MESOPELAGIC FISHES OF THE NEWFOUNDLAND BASIN: THE DISCRETENESS OF PELAGIC FAUNAS

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BY

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ABSTRACT

Samples collected with a large midwater trawl were used to describe the mesopelagic fish fauna of the Newfoundland Basin. This fauna was found to be depauperate relative to fish faunas to the south. Cluster analysis, ordination and recurrent groups analysis of samples from the Newfoundland Basin, Slope Water and Gulf Stream revealed a gradation between faunas rather than discrete groups. The higher diversity of the Slope Water fauna suggested it was an ecotone between a subarctic and subtropical fauna. The results question the presence of communities in pelagic environments.

Comparisons of species composition among samples supported the hypothesis that the North Atlantic Current is an extension of the Gulf Stream with a substantial influence of the Slope Water. Differences in the size composition of faunas were found between the Newfoundland Basin and the Slope Water.

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1 INTRODUCTION

The midwater fish fauna of the Newfoundland Basin has not been adequately described. A very large faunal zone, the Atlantic Subarctic Province, has been proposed based on myctophids from twenty tows (Backus et al. 1977). This province includes the Newfoundland Basin and extends north and east across the North Atlantic. The purpose of this study is: 1) to fully characterize the midwater fish fauna of the Newfoundland Basin, and 2) to compare this fauna with nearby waters, including the Slope Water and the Gulf Stream. An underlying assumption of such a comparison is the existence of discrete faunas or communities.

1.1 The Problem of Pelagic Communities

There has been much argument over the presence, nature and even the definition of biotic communities. Historically, two contrasting views have been introduced. Clements (1916) regarded a community as an "organic entity

with an ontogeny and phylogeny similar to an organism" (also see Tansley 1920, Allee et al. 1949), whereas Gleason (1926) considered groups of organisms to be totally coincidental. There are arguments that deny the reality of communities as natural, discrete units (Whittaker and Woodwell 1973) and yet the basis of community structure is still hotly contested. The individualistic theory, similar to that proposed by Gleason (1926), still has its supporters; however, Clements' (1916) superorganism theory has been replaced by a theory centered around competition. Its supporters emphasize past and present competition in the structuring of communities (see Roughgarden 1983). Individualistic theories suggest local communities are dependent on the autecology, migration and food availability of individual species (Strong 1983). The independent coexistence of species has been termed stochasticity (Grossman 1982, Grossman et al. 1982). A recent issue of the journal American Naturalist (1983, Vol. 122, No. 5) has been devoted to this debate.

There are conceptual problems to the establishment of communities due to the three-dimensionality and dynamic nature of pelagic environments (see Sec. 1.2). Hutchinson (1961) first described the "paradox of the plankton". On

the basis of niche theory and the competitive exclusion principle, he questioned how a number of species could co-exist in a relatively unstructured environment. The lack of sharply defined boundaries poses problems in delimiting communities. Physical properties have been investigated as boundaries but laboratory experiments have shown that pelagic ostracods, for example, can cross "without hesitation" haloclines of 1 ppt in 1 cm and thermoclines of 10°C in 1 cm (Angel 1979).

The lack of barriers to dispersal would seem to preclude the presence of communities because of the high probabilities of mixing of adjacent areas, particularly among organisms that are not highly motile. The high probabilities of advection beyond an organism's range are exemplified by the commonness of expatriates. These organisms survive in areas outside of their normal range but are unable to reproduce (Zurbrigg and Scott 1972). Their persistence over time suggests a constant immigration to the zone of expatriation.

Appreciation of these difficulties led to the water mass hypothesis. This hypothesis attempted to relate species boundaries with those of water masses (see Sverdrup

et al. 1942). Correlations of the distribution of organisms with temperature and salinity have been made for a squid, Vampyroteuthis infernalis (Pickford 1946), a pelagic worm Poeobius meseres (McGowan 1960), chaetognaths (David 1958, Bieri 1959), an opisthoproctid fish Winteria telescopa (Haedrich and Craddock 1968), and fishes of the families Chauliodontidae (Haffner 1952), Melamphaidae (Ebeling 1962, Ebeling and Weed 1963), and Myctophidae (Backus et al. 1965, 1969,1970). The results were rather unsatisfactory as some species were spread across numerous water masses, whereas others were restricted to smaller areas within a single water mass. The fit also varied between oceans being better for the Pacific than the Atlantic. The imperfect fit caused researchers to look for other characteristics of the pelagic environment that could be correlated with distribution. Other parameters found to correlate to varying degrees with species distributions were oxygen content (Haffner 1952, Ebeling 1962, Johnson and Glodek 1975), productivity (Ebeling 1962, Roper 1969, Backus et al. 1970, Pietsch 1974), topography, thermal fronts and currents (Backus et al. 1970).

The numerous exceptions to the hypothesis suggested a refinement was necessary. Communities or faunal groups,

rather than individual species, were then examined for patterns. Different studies, using a variety of statistical treatments and a variety of organisms, related these faunal groups to hydrographic conditions (Fager and McGowan 1963, Loeb 1979, Barnett 1975, 1983, Fasham and Angel 1975). These communities have been suggested to be structured by coadaptation of species and the importance of biological interactions has been stressed (Johnson 1974). Problems arose because some organisms seem to co-occur quite regularly and yet not all organisms respond to environmental gradients in the same way (McGowan and Williams 1973, Pugh 1975). The hypothesis was criticized because of the failure to take into account the place of origin of taxa, dispersal routes, and variation due to hydrological, ecological, and climatological phenomena (van der Spoel and Pierrot-Bults 1979). Also, results could be dependent on the scale of sampling (Fasham and Angel 1975). Although these problems are realized, contemporary studies continue to use essentially the same approach.

1.2 Local Physical Oceanography and Distribution Patterns

The preceding discussion indicates the importance of understanding the local hydrography when looking at the distribution of pelagic species. The hydrography off the east coast of Canada is very dynamic and complicated. There is still some question as to the characteristics of water movement to the east of the Grand Banks. Two currents exert a major influence on the hydrography, the Labrador Current and the Gulf Stream (McLellan 1957). Three distinct hydrographic regimes can be distinguished, two by the above currents and a third called the Slope Water, a body of water whose southern limit is the Gulf Stream and which is bounded to the northwest by the continental shelf and to the northeast by the Grand Banks of Newfoundland (Gatien 1976). Each of these is outlined in Figure 1 and will be discussed in detail in the sections that follow.

Very little faunal work has been done in the northern part of this system. No samples from the cold waters south of the Flemish Cap were used to characterize the Atlantic Subarctic Province (Backus et al. 1977). Samples used were from east of the Flemish Cap and further north across the

North Atlantic. Cram (1983) has described myctophid by-catch from along the edge of the continental shelf of Labrador.

There has been considerable work on the Gulf Stream and Slope Water systems further south. Phytoplankton species assemblages have been contrasted between the Slope Water and the Northern Sargasso Sea by Hulburt and various co-workers (Hulburt et al. 1960, Hulburt and Rodman 1963, Hulburt 1967). Comparative studies have primarily resulted from interests in cold core rings and their effects on faunas of the northern Sargasso Sea (Wiebe et al. 1976, Ortner et al. 1978, 1979, Ring Group 1981, Backus and Craddock 1982).

1.2.1 Gulf Stream System

The Gulf Stream is one of the most studied current systems in the world and yet there are still questions regarding its flow. Iselin (1936) originally described the Gulf Stream System as three parts: 1) the Florida Current which originates from the Gulf Equatorial Current and flows north along the edge of the continental shelf to an area

near Cape Hatteras, 2) the Gulf Stream, which continues from this area where the current turns away from the shelf and extends east to a region east of the Grand Banks at about 45°N latitude and 3) the North Atlantic Current which covers all easterly and northerly currents from the area east of the Grand Banks. The three subdivisions are not entirely accepted in practice but are useful in describing the system (Fofonoff 1981). Of most interest in the present context is the transition from Gulf Stream to North Atlantic Current. This is a poorly understood, complicated area characterized by meanders and anticyclonic eddies.

The Gulf Stream is often misrepresented as an individual distinct current. It is better thought of as a rapidly moving western edge of the Sargasso Sea, evidenced by the sharp definition of the stream on its northwest side but less so on its southeast side towards the gyre (Pickard and Emery 1982). Average speed is 150 cm/s and average width is 115 km (Pickard and Emery 1982). Although roughly delineated by temperature (15-17.5°C), it is a zone of steep horizontal density gradient with the edges defined where the density gradient is zero (Worthington 1954, Stommel 1965). It is also readily identified by its low

oxygen content (Gatien 1976).

Meanders - wavelike patterns in the route of the Gulf Stream - are common, although cause of formation is poorly understood. The best explanation incorporates a steering of the current by topography as well as barotropic and baroclinic forms of hydrodynamic instability (Saunders 1971). There is some question as to the effects of bottom topography as it is not known whether the Stream extends to the bottom in all areas along its length (Fofonoff 1981). Meanders can pinch off and separate from the Gulf Stream to form rings or eddies. Both warm and cold core rings are formed, in the Slope Water and Sargasso Sea respectively (Parker 1971, Saunders 1971). Rings can be traced up to one year after their formation and either dissipate or become reincorporated with the Gulf Stream.

Two distinctly different hypotheses have been proposed regarding the continuation of the Gulf Stream and the formation of the North Atlantic Current. Worthington (1962, 1976) proposed two gyres for the North Atlantic separated by a trough of low pressure extending to the southeast from the Tail of the Grand Banks. No water from the Gulf Stream would be in the North Atlantic Current as the Gulf Stream

turns southeast after passing 50°W longitude to enclose the southern gyre. The North Atlantic Current is the western edge of the northern gyre. He proposed the two gyre system to explain why water transported north past the Flemish Cap had higher concentrations of oxygen in the pycnocline than that transported by the Gulf Stream west of 50°W.

The other hypothesis is similar to the original ideas of flow in the North Atlantic. Earlier studies suggested the Gulf Stream separated into multiple branches, the northern branch being the strongest and making up the major portion of the North Atlantic Current (Iselin 1936, Sverdrup et al. 1942, Fuglister 1963). Data were few and direction of currents east of the Grand Banks were speculative. Mann (1967) and later Clarke et al. (1980) supported this hypothesis. The North Atlantic Current was proposed to originate from a combination of water from the Gulf Stream and the Slope Water Current. Furthermore, a small gyre to the east of the Flemish Cap seemed to reinforce this flow.

The Gulf Stream System undoubtedly influences the distribution of pelagic organisms, the major effect being a northern extension of the range of subtropical and tropical

species (Angel 1979). The majority of faunal work has been restricted to the Gulf Stream portion of the system, particularly in the area between the east coast of the United States and Bermuda (Grice and Hart 1962, Hulburt and Rodman 1963). The Gulf Stream has been described as a faunal boundary for phytoplankton (Hulburt 1964), zooplankton (Grice and Hart 1962) and mesopelagic fishes (Backus et al. 1970). The fish fauna has been suggested to be intermediate between that of the Slope Water and the Northern Sargasso Sea (Jahn and Backus 1976). No attempt has been made to resolve the problem of the direction of flow of the Gulf Stream at the Tail of the Grand Banks using faunas. Zurbrigg and Scott (1972) used Worthington's (1962) hypothesis to suggest a possible source for expatriate Myctophum punctatum near the Flemish Cap but they did not examine the complete fauna to support either of the two hypotheses.

1.2.2 Slope Water

The Slope Water Region is a very complex, dynamic body of water which lies between the Gulf Stream and the edge of

the continental shelf from Cape Hatteras to the Tail of the Grand Banks. McLellan (1957) described it as a single, well-defined water mass where transition between regions was not gradual but involved the crossing of sharp boundaries. Later work denied the existence of a definite, characteristic temperature-salinity relationship (Lee 1970), and some noted a boundary zone within the Slope Water (Fuglister 1963). McLellan (1957), using sigma-t surfaces, described the Slope Water as being a mixture of 73 to 83 % Central Atlantic Water and the remainder Coastal Water, a thin band of water along the shelf edge. This Coastal Water was predominantly influenced by the Labrador Current. Gatien (1976) revised this outlook. She postulated that there were two zones in the Slope Water. A northern section, predominantly influenced by the Labrador Current and called the Labrador Slope Water, is poorly mixed and gradually gets warmer moving east to west. The southern section, Warm Slope Water, is dominated by the Gulf Stream, is warmer in the east and well-mixed in the north-south direction. She suggested that this southern section represented the area of distinct temperature-salinity curves found by McLellan (1957). The zones do overlap as the Labrador Slope Water includes all

the water below 500 m. Hydrographically, this makes for a very complex region of mixing waters.

The Slope Water has been said to support a distinct fauna of myctophids (Backus et al. 1977) and other mesopelagic fishes (Jahn and Backus 1976). Markle et al. (1980) describe Slope Water species that have been advected onto the Scotian Shelf. As stated earlier, the Slope Water fauna has been compared with that of the Northern Sargasso Sea (Jahn and Backus 1976). However, comparisons have not been made with faunas to the north in the Newfoundland Basin. Considering the physical make-up of the Slope Water, comparison between it and the Newfoundland Basin is critical in telling whether the Gulf Stream turns south at the Tail of the Grand Banks.

1.2.3 Labrador Current

The Labrador Current is the dominant hydrographic feature of the Newfoundland Basin. It originates from a merging of the Baffin Island Current and the West Greenland Current at Hudson Strait. Some contribution is also made to it from Hudson Bay, primarily of cold, fresh water (Smith

et al. 1937). It is a cold current 0°C or less off Labrador (Lazier 1982, Pickard and Emery 1982) to 4-5°C near the Flemish Cap (Clarke et al. 1980) with relatively low salinity (30-34 ppt) (Pickard and Emery 1982). Density differences throughout the current are primarily maintained by temperature (Warren 1981). It flows south along the edge of the continental shelf of Labrador, splitting into an inshore branch, which flows through the Avalon Channel, and an offshore branch, which flows through the Flemish Pass (Clarke et al. 1980, Petrie and Anderson 1983). High oxygen and low silica values show that the current continues around the Tail of the Banks (Warren 1981). However, current meters have not given clear, direct evidence of this flow (Clarke et al. 1980).

No pelagic faunal studies have been done in the Labrador Current. Zurbrigg and Scott (1972) comment on some of the species captured with Myctophum punctatum off Newfoundland but they do not attempt comparisons with other areas. Cram (1983) described the distribution of myctophids along the shelf edge off Labrador.

The Newfoundland Basin lies south of the Flemish Cap between the Labrador Current and the North Atlantic

Current. Hydrographic studies have concentrated on sections to the north, to follow the flow of the Labrador Current, and to the south, to follow the route of the Gulf Stream at the Tail of the Grand Banks. In spring and summer there is recirculation of Labrador Current water in the Newfoundland Basin as the current turns north-east at the Tail of the Banks and flows north inside the North Atlantic Current (Clarke et al. 1980). Satellite photos suggest the presence of of surface mixing, but the extent is unknown. There has been a suggestion of eddies advecting into the area (ICNAF Redbook 1978) but this is not well documented.

1.3 Objectives

From the above synthesis it is evident that the hydrography of the oceanic waters off Newfoundland is very dynamic, with large amounts of mixing taking place. Two of the three hydrographic regimes have had their faunas described. To understand the system fully a description of the third regime, the Labrador Current/Newfoundland Basin, must be included. The first objective of this study is to describe the mesopelagic fish fauna of the Newfoundland

Basin.

The dynamic nature of the hydrography off Canada's east coast would seem to preclude distinct faunas. However, distinct faunal groups have been found in dynamic environments. In a region of known faunal mixing off the coast of California organisms group themselves in association with physical parameters such as depth, season, and distance offshore (Ebeling et al. 1970). Jahn and Backus (1976) suggested distinct faunas in their study of mesopelagic fishes in the same hydrographic regime, the Slope Water, Gulf Stream and Northern Sargasso Sea. Despite the fact that it is an interacting hydrographic system there are discrete parts ranging from very cold, fresh water (0°C, 32.6 ppt) to warm, saline water (20°C, 36.4 ppt). The range in temperature and salinity is about as large as is possible in the entire ocean. If oceanographic conditions are important in determining faunal composition then this discreteness should be reflected in the faunas. The second objective of the study is to investigate this premise.

A variety of techniques are available for analytically separating groups and describing their cohesiveness. In

faunal studies one technique is usually employed: recurrent groups analysis (Fager and McGowan 1963), cluster analysis (Jahn and Backus 1976) or ordination (Ebeling *et al.* 1970). The choice of analytical technique may predetermine the result. Application of a number of techniques is necessary to assess past work. The question is, are the results compatible? If an underlying structure is present in the data, i.e. if communities exist, then the results should be similar. The third objective of the study is to apply a number of analytical techniques to the same data set to see if results do differ enough to affect the interpretation.

2 GEAR, MATERIALS AND METHODS

2.1 Sampling Pelagic Systems

The deep pelagic environment is one of the most difficult to sample because of our inability to make adequate direct observation. What we do know is based on samples from different types of gear, all of which bias the catch in some relatively unpredictable way. Each sampling devite gives a different "window" into the pelagic environment (Robison 1972, Angel 1977).

What gear, or types of gear, give the best "window", that which best approximates reality? To get an accurate representation of the species assemblage two questions must be addressed: 1) is the gear catching everything that is present and across all size ranges?, and 2) are patchy distributions biasing the abundance relationships among the species present?

Large nets have been shown to decrease net avoidance

and therefore increase the capture of rare fish as well as larger individuals of the more common species (Harrisson 1967, Willis and Pearcy 1982, Kashkin and Parin 1983, Pearcy 1983b). Smaller nets tend to catch only the more abundant species (McGowan 1971). Simulation and field studies have shown a reduction in bias due to patchiness for samples from large nets (Wiebe and Holland 1968, Wiebe. 1971). Similarly, Angel et al. (1982) found that an RMT8 sample (classified as a medium size net (Pearcy 1983a)) was an order of magnitude too small to assess the community accurately.

Though these advantages are known very few studies actually use large nets. The majority of oceanographic research vessels are unable to set and retrieve this gear because of inadequate space, and few vessels are equipped to trawl with large nets to depths greater than 1000 m (Pearcy 1983a). Opening-closing devices have not been designed for the very large nets. Fasham and Angel (1975) argue for the use of such devices because water masses, and therefore faunas, may overlap at depth. For distributional studies, only Brandt (1981) and Griffiths and Brandt (1983a,1983b) in their studies around eddies, and Krefft (1974, in Pearcy 1983b) have used large Engels midwater

trawls.

2.2 Data Collection

Engels 80-630 midwater trawls were used for collection of samples in this study. These nets have a mouth opening of approximately 600 m^2 (Brandt 1981, Kashkin and Parin 1983). Mesh size in the wings is graded, ranging from 81.3 cm stretched mesh near the headrope to 10.2 cm stretched mesh near the codend, with a codend liner of 2 mm stretched mesh. A disadvantage of these large nets was found during Gadus Atlantica 62 (GA62). In very rough seas encountered during this cruise, a number of large trawls were torn beyond repair. Brandt (1981) reported similar problems during his sampling. For the remainder of samples during GA62 a smaller Sputnik 1600 trawl (43 m headrope, mesh in codend 40 mm with 2 mm lining) was substituted.

Collections were obtained from four cruises, Belogorsk 79-03 (Mar. 28/79-Apr. 13/79), Belogorsk 79-04 (Apr. 27/79-May 4/79), Gadus Atlantica 51 (May 1981), and Gadus Atlantica 62 (Feb. 21/82-Mar. 7/82). A total of 69 collections were made (Fig. 1 and Table 1). All tows were

approximately one half hour at fishing depth. Three depth strata were sampled: 100 m (night only), 500 m and 1000 m. No opening-closing devices were used.

Hydrographic data were collected at the beginning of each tow. Reversing bottles were used on the Belogorsk and Gadus Atlantica 62 cruises, and a conductivity-temperature-depth probe (CTD) was used on Gadus Atlantica 51. Expendable bathythermographs (XBT) were also used on Gadus Atlantica 62. Using these data, samples were classified by their 200 m temperature as Northern Sargasso Sea (>17.5°C), Gulf Stream (15-17.5°C), Slope Water (9-15°C), or Newfoundland Basin (<9°C) (Worthington 1964, Jahn and Backus 1976). Temperature and salinity profiles were plotted for individual transects.

Specimens were identified to species and minimum and maximum standard length were recorded for each species lot (total length for eels). For some collections all fish were measured and weighed. Recent revisions of many pelagic families aided in the identification. Some of the authorities used include: Alepocephalidae (Markle 1977), Anoplogasteridae (Woods and Sonoda 1973), Astronesthidae and Idiacanthidae (Gibbs 1964a,b), Bathylagidae,

Argentinidae and Opisthoproctidae (Cohen 1964), Bregmacerotidae (D'Ancona and Cavinato 1965), Caristiidae (Scott et al. 1970), Ceratiidae, Linophrynidae and Oneirodidae (Bertelson 1951) and Oneirodidae (Pietsch 1974), Chauliodontidae, Malacosteidae, and Stomiatidae (Morrow 1964a,b,c), Chiasmodontidae (Liem and Scott 1966), Diretmidae (Woods and Sonoda 1973, Post 1976), Evermannellidae (Johnson 1982), Gonostomatidae (Grey 1964), Macrouridae (Marshall and Iwamoto 1973), Melamphaidae (Ebeling and Weed 1963), Melanostomiatidae (Morrow and Gibbs 1964), Myctophidae (Nafpaktitis et al. 1977), Nemichthyidae (Nielson and Smith 1978), Paralepididae (Rofen 1966), Saccopharyngidae and Eurypharyngidae (Goode and Bean 1896), Scopelosauridae (Johnson 1974), Searsidae (Parr 1960), Serrivomeridae (Beebe and Crane 1936), Sternoptychidae (Schultz 1964, Baird 1971), and Stromateidae, Nomeidae and Centrolophidae (Haedrich 1967).

2.3 Faunal Analyses

Species that occurred only once were considered sufficiently rare to warrant removal from the data set.

Removal of rare species is necessary because the occurrence of rare species is usually more a matter of chance than an indication of ecological conditions. Rare species have little effect on multivariate techniques because they carry such a small part of the overall variance and some techniques see rare species as outliers, obscuring the analysis of the rest of the data set (Gauch 1982).

The species abundance data were transformed to rank abundance to account for variations in gear, tow length, time of day, and other factors which could affect overall abundance. Difficulties in accurately assessing abundance, due to inaccuracies of sampling, preclude its use in faunal studies (see Cassie 1963, Wiebe 1972, Angel 1977). However, some indication of abundance relationships is important because differences between zones can be dependent on the relative abundance of species rather than strictly presence or absence (Fasham and Angel 1975). Ranks retain abundance relationships and it has been suggested that they can be assessed more accurately than absolute abundance (Fager 1957, Goodall 1973). Using McGowan's (1971) rank accuracy simulation the ranks in this study are accurate up to about rank six.

To examine variability introduced by the two types of sampling gear, Kendall's tau rank correlation tests were performed on samples taken in similar locations with the two types of gear. These comparisons could only be made between cruises. Of the five sets of samples compared, only one showed a significant difference in the species' ranks. This pair of samples was in an area of different hydrographic characteristics between the two cruises.

To make spatial comparisons of species composition it is necessary to pool samples into real, or if necessary artificial, groups based on group characteristics. Classification and ordination are two methods of analyzing sample-by-species abundance matrices to search for patterns in the data (Green 1980, Gauch 1982).

A hierarchical cluster analysis was performed on the matrix of species rank-abundance versus samples using the CLUSTAN package (Wishart 1978). The nonmetric Bray-Curtis index of dissimilarity was used to measure the affinity between samples. This index is not affected by joint absences (Field and McFarlane 1968) and is algebraically equivalent to the Czekanowski index (Field et al. 1982) which Bloom (1981) found to be the most accurate at

assessing similarity. Samples were clustered using the unweighted pair-group method which joins two groups of samples at the average level of similarity between all members from each group (Sokal and Sneath 1963). This method of clustering has been shown to be the most reliable. (Field et al. 1982).

There are some disadvantages to clustering including the fact that it can force graded series into discrete clusters (Field et al. 1982). The best approach is to compare the classification results with some type of ordination (Green 1980, Field et al. 1982, Gauch 1982). Ordination reduces the dimensionality of the data and allows a plot where the distance between stations is indicative of their similarities (Gauch 1982). Detrended correspondence analysis (DCA) was performed using the DECORANA program from the Cornell Community Ecology Program Series (Hill 1979). This gives an objective, community-centred ordination, especially with heterogenous or difficult data sets (Gauch 1982). DCA, an eigenvector technique, has been shown to be superior to nonmetric multidimensional scaling (MDS), reciprocal averaging, polar ordination and principal components analysis (Gauch et al. 1977, Gauch et al. 1981). MDS has been suggested to be

better for ecological data (Field et al. 1982), but it requires more computer time and two subjective choices not needed for DCA: a number of dimensions, which is difficult to assess (Green 1980), and a distance measure (Gauch 1982). Another advantage to DCA is that it gives a meaningful scaling to the ordination axes (Hill 1979, Gauch 1982). The unit of distance along a gradient may be called a standard deviation (sd) as the root-mean-square standard deviation of the species-abundance profiles is approximately one (Hill 1979). Samples separated by greater than four sd units will generally have no species in common.

A third technique that has been used in faunal studies is recurrent groups analysis. This technique involves a search for species that are frequently members of each others' environment (Fager 1957). Species are said to show a positive affinity if the index of affinity is equal to or greater than 0.50 (Fager and McGowan 1963, Venrick 1971). The index of affinity is based on joint occurrences of species pairs:

$$I=[J_{ab}/[N_a N_b]^{.5}]-[1/2N_b]^{.5}$$

where N_a and N_b, are the total occurrences of species a and b, J_{ab} is the number of joint occurrences, and $N_b > N_a$ (Fager 1957, Fager and McGowan 1963, Venrick 1971, McGowan and Walker 1979). Species are then arranged into groups with the maximum number of affinities. Associates are species which are not assigned to a group but are present only with members of a particular group (Fager 1957). To reduce the number of calculations, only those species which were present in greater than 5% of the samples were included in the recurrent groups analysis.

3 RESULTS

3.1 Hydrography

Two transects illustrate the hydrographic properties for the four cruises (Fig. 1). Transect A-B, from 1979, is through the Slope Water and across the Gulf Stream. Transect C-D, from 1981, runs east-west from the Grand Banks, through the Newfoundland Basin, to the North Atlantic Current. Temperature and salinity profiles are shown for each transect (Figs. 3 to 6).

Two fronts were evident in the temperature and salinity profiles in 1979 (transect A-B, Figs. 3 and 4). The majority of the profile represents Slope Water, with the Gulf Stream to the right at the southern end of the transect. Temperatures at 200 m ranged from 9 to 15°C. Mixing is evidenced by the bending of isotherms and isohalines. The vertical weaving of the 12°C isotherm on the Slope Water side of the Gulf Stream shows that

interleaving of water is occurring along the front. A second, south-westward flowing current carrying cooler, less saline water is evident in the northern part of the Slope Water. Adjacent profiles show this current becoming warmer and more saline as it moves west. Other sections from samples in this area show similar characteristics.

The second transect, C-D, runs along 45°N latitude from the edge of the continental shelf off Newfoundland to an area south of the Flemish Cap (Fig. 1). Two fronts are evident in both the temperature (Fig. 5) and salinity (Fig. 6) profiles. The Labrador Current runs south along the continental shelf and the North Atlantic Current runs north at the eastern edge of the transect. The front bounding the Labrador Current to the east does not extend to great depth. Most of the profile shows relatively uniform temperature and salinity at depths greater than 200 m.

The two transects have interesting similarities. The first transect (Fig. 3 and 4) is warmer and more saline, but both contain two fronts at their extremes with an area of mixing between. Figure 3 shows evidence for stratification whereas figure 5, representing the Newfoundland Basin, is uniformly cold. The North Atlantic

Current front (Fig. 5) is as strong as the Gulf Stream front (Fig. 3).

3.2 Midwater Fish Faunas

A total of 26,527 fish, representing 56 families, 104 genera, and 168 species were identified. Myctophidae was the dominant family by number (86.7%). Other families represented include Gonostomatidae (5.2%), Stomiatidae (1.3%), Sternoptychidae (1.1%), Bathylagidae (1.1%), Chauliodontidae (1.0%), Paralepididae (0.4%), Serrivomeridae (0.4%), Melamphaidae (0.3%), Melanostomiatidae (0.1%), Diretmidae (0.1%), Malacosteidae (0.1%), and Scopelosauridae (0.1%). Myctophids were dominant in 65 collections, Gonostomatids were dominant in the other four samples.

Twenty-eight families were present among the 6760 fish captured in the Newfoundland Basin (Appendix A). Fishes of the family Myctophidae dominated the catches (87.5%). Of these 95.4% were one species, Benthosema glaciale. Other families present included Stomiatidae 4.1%, Bathylagidae 3.1%, Chauliodontidae 1.5%, Gonostomatidae 1.1%,

Serrivomeridae 0.8%, Paralepididae 0.3%, and Sternoptychidae 0.3%. Most species occurred infrequently. Of the 51 species identified, 22 occurred in only one sample and only 8 species occurred in five or more samples. These species are: Benthosema glaciale, Protomyctophum arcticum, Chauliodus sloani, Stomias boa ferox, Serrivomer beani, Bathylagus euryops, Notolepis rissoi kroyeri and Borostomias antarcticus.

Few of the major families in the Newfoundland Basin were represented by more than one species. Stomias boa ferox was the only stomiatid, Chauliodus sloani represented the Chauliodontidae, Bathylagus euryops the Bathylagidae, Serrivomer beani the Serrivomeridae, and Notolepis rissoi kroyeri the Paralepididae. Fourteen species of myctophids were present although two species, Benthosema glaciale and Protomyctophum arcticum, comprised 98.7% of the individuals. There were three gonostomatids - Cyclothone braueri, C. microdon and Gonostoma elongatum - and two sternoptychids, Sternoptyx diaphana and Argyropelecus aculeatus.

Average sample richness was 14.2 species. For 500 m tows the mean was 8 species. These differences can

primarily be attributed to rare deep-living stomiatoids and ceratioids. There was little change in species ranking with depth.

To classify all samples based on their faunal composition a cluster analysis was used. It revealed four groups at 25% similarity (Fig. 7). Generally, sample similarities are low, the first clustering occurring at 70%. There is some concordance between clusters and samples grouped by temperature at 200 m but there are 26 missclassifications. Clusters represent a Newfoundland Basin Fauna, a Slope Water Fauna, and a Gulf Stream Fauna. The fourth group is difficult to reify. It contains samples from a single cruise through water with Slope Water, Gulf Stream and Northern Sargasso Sea characteristics. All were taken sequentially at the far southwestern edge of the sampled region. Five of the seven samples in this group were dominated by species, particularly Bonapartia pedaliota, that did not show high abundances in any other sample.

The Newfoundland Basin Fauna was comprised of samples from the Newfoundland Basin plus samples of similar species composition from the Slope Water. The dominant species in

all samples from the Newfoundland Basin Fauna was Benthosema glaciale. Percent dominance by this species ranged from 47.0% to 99.0% (mean=78.8%, sd=14.45). Species richness was the lowest of the three faunal groups (Fig. 8). Other common species were Protomyctophum arcticum, Bathylagus euryops, Serrivomer beani, Stomias boa ferox, Chauliodus sloani, Notolepis rissoi kroyeri and Sternoptyx diaphana.

The Slope Water Fauna had the highest average sample richness (Fig. 8). Variability was high and, consequently, predictability low. B. glaciale was the dominant species in 15 samples, Ceratoscopelus maderensis in 5 samples, Lobianchia dofleini in 2; and Hygophum benoiti, Notoscopelus caudispinosus, Ceratoscopelus warmingii and Bolinichthys indicus were dominant in one sample each. Although rarely dominant, C. maderensis and H. benoiti are important members of this fauna. Some patterns may be related to patchy distributions. N. caudispinosus, for example, was not abundant with any regularity in the other samples. Percent dominance of Slope Water samples averaged 45.0% (14.4%-91.6%). Samples can be divided into two groups, those with B. glaciale dominant and those without. Mean percent dominance by this species is 52.1 (15.5-91.6)

and .36.15 (14.4-73.1) respectively. Other prevalent species include Gonostoma elongatum, Lampanyctus pusillus, Vinciguerria attenuata, Lobianchia gemellarii and Hygophum hygomii.

Average sample richness of the Gulf Stream Fauna was lower than the Slope Water Fauna (Fig. 8). Ceratoscopelus maderensis and C. warmingii were the dominant species in six samples each out of the eighteen samples in the group. Average percent dominance was 47.3% (range 16.9-87.6%). Other prominent species from the pooled catches were Hygophum benoiti, H. hygomii, Lepidophanes guentheri, and Lampanyctus pusillus.

Some species do occur regularly through all the faunal groups. This is particularly common between the Gulf Stream and Slope Water Faunas. Species that occur throughout the collections are B. glaciale, C. maderensis, H. benoiti, Bolinichthys indicus and Chauliodus sloani. Others that are less dominant but still occur regularly are H. hygomii, G. elongatum, Stomias boa ferox, and L. pusillus.

The results were also analyzed by ordination. The first two factors of the DCA analysis described 44.3 and

23.7% of the variation respectively. Addition of the third and fourth factors, describing 15.4 and 13.5%, did not aid in group separation. The different faunas outlined in the cluster analysis are not readily apparent on a plot of the first two ordination axes (Fig. 9). The lines superimposed on the figure enclose samples of similar hydrographic characteristics. There are very large areas of overlap for samples from different hydrographic regimes.

Figure 10 is the same ordination plot with lines enclosing samples that were grouped together by the cluster analysis. The amount of overlap between groups shows that faunas are not as different as the cluster analysis suggests. It would be difficult to pick out faunas from the ordination results if the two plots did not have the cluster results or hydrography superimposed. Groups are not easily distinguished by the ordination technique alone because within-group similarity is as great as between-group similarity. The fact that there is little intergroup difference at the peripheries suggests a gradation between faunas.

DCA gives a meaningful scale to the axes. Samples less than four standard deviation units apart have species

in common (Hill 1979). Almost all samples have species in common, from the Gulf Stream to the Newfoundland Basin. Only the samples at the extremes of the first axis are completely different. There is only a 50% change in species composition between any two group centers. The relative similarities in species composition between adjacent groups are further evidence for a gradation between faunas.

The third technique employed was recurrent groups analysis (Fager 1957, Fager and McGowan 1963). This analysis identified two small groups, each with one associate member (Table 2). Few species were frequent members of each other's environment. Of the 67 species included in the analysis only six were placed in groups. All species in both groups are widespread. Both groups are closely related as all members of group 2 show positive affinities with both Bolinichthys indicus and Hygophum benoiti in group 1. Generally, Group 1 species are more abundant in the southern collections and Group 2 species are more abundant in the northern collections.

4 DISCUSSION

4.1 The Fauna of the Newfoundland Basin

Compared to surrounding regions to the south and east the fauna of the Newfoundland Basin is relatively depauperate. There were fewer species per family there than in the Slope Water or Gulf Stream (Table 3).

Backus et al. (1977) collected three samples from the Newfoundland Basin and included them in the Subarctic Province. There are some distinct similarities between samples due to the domination of myctophids in the collections. In both cases Benthosema glaciale makes up greater than 95% of the myctophid species. Other myctophid species, such as Protomyctophum arcticum and Ceratoscopelus maderensis, show similar abundances in the two studies.

Backus et al. (1977) describe Myctophum punctatum as the second most abundant species in the Subarctic Province. Unpublished data from the M/V Brandal in 1968 using a large

Engels trawl show M. punctatum comprising 84% and B. glaciale 1.6% of myctophids from two tows south of the Flemish Cap (45°30'N, 47°30'W). M. punctatum makes up less than 0.2% of the myctophids in my samples.

Although present in subarctic waters, the regions of greater abundance of M. punctatum are in temperate waters (Nafpaktitis et al. 1977). Large numbers of M. punctatum could be advected from the center of their range in the Slope Water. Warm-core rings could be responsible as recently they have been reported as far north as the Flemish Cap (ICNAF Redbook, 1978). However, my data suggests that this species is not abundant in the Slope Water and there were few other Slope Water species present with M. punctatum in the Brandal collections. No particular cause for the difference is evident. Long term variation in the abundance of pelagic fish is well known for commercial stocks but it has not been observed in mesopelagic fishes.

4.2 Discreteness of Assemblages

A general assumption is that distinct faunal groups

exist in oceanic environments. This conclusion is a result of numerous studies, primarily in the Pacific, on organisms ranging from diatoms (Venrick 1971) to fishes (Jahn and Backus 1976, Loeb 1979, Barnett 1983, Willis 1984). Few studies utilize the range of available statistical techniques to search for patterns. This could lead to misleading results. For example, recurrent groups analysis relies on presence/absence data. Faunal differences could result from variations in abundance of species (Fasham and Angel 1975). Classification can force graded series into discrete clusters (Field et al. 1982) and is best used in conjunction with other techniques such as ordination (Green 1980, Gauch 1982).

Groups can be isolated in my data but there is a gradation between faunas rather than abrupt change. This gradation is evident in the ordination plots but evidence is also available from the characteristics of the individual faunas. The Slope Water Fauna shows the characteristics of the assemblages in an ecotone. An ecotone is a transition zone between two types of communities and can be characterized by a high diversity and by the presence of species from both of the overlapping groups (Odum 1971). The Slope Water Fauna has a greater

number of species than the Newfoundland Basin and the Gulf Stream and contains both subarctic and subtropical species. Therefore, the Slope Water can be considered an ecotone between a northern and a southern fauna. Because of the gradation, few species are associated, suggesting individual species responses to environmental factors. Consequently, faunas become an artifact of individual group member occurrences at any particular location.

This view is in contrast to other faunal studies in both the Pacific and Atlantic Oceans. They have concluded that specific species are usually associated and that distinct faunas are present (Rager and McGowan 1963, Venrick 1971, McGowan 1971, 1974, Fasham and Angel 1975, Jahn and Backus 1976). Fasham and Angel (1975) in their study of pelagic ostracods admit the possibility that "the situation is more likely to be that of a continuously varying population with the zones representing different stages along the variation" and that differences between faunal zones may in fact be clinal without clear boundaries. Similar conclusions have been reached in terrestrial studies where habitat changes could be more abrupt. Kaiser et al. (1972), studying birds and mammals, found that changes in species composition are characterized

by gradual shifts over large zones of transition, not by breaks between homogeneous areas.

Similarities are evident in the species composition of samples from the Slope Water and Gulf Stream between my work and that of Jahn and Backus (1976). This suggests that although different gear was used, similar faunas were sampled. Similarities are also evident in the dendrogram. Nevertheless, there are differences in the interpretation. They reported distinct faunas, particularly for the Slope Water and the Northern Sargasso Sea, with the Gulf Stream intermediate between the two. This seems difficult to justify empirically as the Gulf Stream is said to be a fast moving section of the Sargasso Sea (Pickard and Emery 1982). On the other hand the Slope Water is a region known for its dynamic qualities due to the amount of mixing between the Labrador Current and the Gulf Stream (Gatien 1976). Therefore, the hydrography dictates the comparison of faunas of the Gulf Stream and the Slope Water with the Newfoundland Basin. As stated above, this comparison shows the Slope Water Fauna to occupy an ecotone between a subarctic and subtropical fauna.

4.3 Continuity of the Gulf Stream

The faunal similarities observed support the hypothesis that the Gulf Stream splits and turns north (Mann 1967, Clarke et al. 1980). Mann (1967) suggests a mixture of both Slope Water and Gulf Stream to form the North Atlantic Current. Faunistically, the Slope Water appears to be dominant. Earlier studies supported Worthington (1962, 1976) because of eastern Atlantic components to the fauna near the Flemish Cap (Zurbrigg and Scott 1972). Also, the northern gyre was used to explain the presence of expatriated Myctophum punctatum. Dispersal was thought to be aided by the westward flowing southern border of the northern gyre from reproductive populations in the eastern Atlantic (Zurbrigg and Scott 1972). Electrona risso is the only eastern Atlantic species present in my samples from the North Atlantic Current. However, it is also present in Slope Water samples and its presence in the North Atlantic Current could be attributed to dispersal from the Slope Water and Gulf Stream.

4.4 Size Relationships

Comparisons of size of single species across fronts were made in a series of papers on warm-core eddies in the Tasman Sea (Brandt 1981, Griffiths and Brandt 1983a, 1983b). There was little consistency in the direction of the trend across the front. For both myctophids (Brandt 1981) and decapod crustaceans (Griffiths and Brandt 1983a, 1983b) some species were larger inside the eddy than out and others were larger outside the eddy than inside. Size was suggested to be related to intraspecific growth variation due to differences in the thermal environment and diet (Brandt 1981, Griffiths and Brandt 1983a). For some species of crustaceans it was suggested that the size differences were due to variations in the timing of reproduction and recruitment, within the same species, inside and outside the eddy (Griffiths and Brandt 1983b).

Interspecific size comparisons between physical regimes have only been reported from taxonomic studies of families of fishes. In the scopelarchids, larger species are present outside rather than inside the central gyres (Johnson 1974). Larger species were also evident in boreal rather than tropical waters (Johnson 1974). In the family

Melamphaidae, the larger species inhabit the more productive boreal and eastern tropical water masses whereas the dwarf species inhabit the relatively sterile western equatorial and central water masses (Ebeling 1962).

Differences in the maximum size of fishes from different hydrographic regimes were evident in my data. The maximum size of species present in each sample was more evenly distributed across the size range and greater in the Newfoundland Basin (Fig. 11). The same pattern was evident intraspecifically. Larger fish made up a greater proportion of the population of Benthosema glaciale (Fig. 12) in a sample from the Newfoundland Basin than in a sample from the Slope Water.

Greater maximum size of B. glaciale is attained in more northern waters off Greenland and Norway (Halliday 1970). Halliday (1970) suggests that northern individuals have a longer lifespan although growth rates are similar. The presence of three age classes of B. glaciale in the Slope Water suggests recruitment to the Newfoundland Basin fauna from the Slope Water or faster growth with a similar maximum size in the Newfoundland Basin.

It is difficult to account for the absence of large

individuals of any species in the Slope Water and Gulf Stream. Productivity alone does not seem adequate to explain the differences in size structure of the two faunas because of the absence of smaller individuals in the Newfoundland Basin. The large size and absence of small individuals of B. glaciale suggests the possibility of expatriation but Halliday (1970) found no evidence of expatriation in his study of the species.

4.5 The Problem of Pelagic Communities: Revisited

Questions have been raised about the assumption that biological interactions are important in structuring oceanic communities. Roe (1974) and Haury (1976), both found the composition and relative abundance of macrozooplankton were changing constantly. In their review, Haedrich and Judkins (1979) suggested the particular species assemblage found is just as dependent on time of day and ontogenetic stage of the organisms as it is on any other factor. Williams et al. (1981) proposed an entirely probabilistic model to describe diatom species distributions. They suggested that groups of species be

called "species assemblages ... without any implication of other than stochastic association unless the nature of that association can be specified" (Williams et al. 1981).

The key to this statement lies in the "nature of the association." To date it has been assumed that if species recur then communities exist. A high concordance of independent species would be expected for species that were all affected by similar factors (Strong 1983). An important part of any definition of biological communities is the interaction of species with other species and their environment (Mills 1969). Haedrich and Judkins (1979) suggest that interactions among macrozooplankton may be "fleeting, and perhaps even random." Of the many studies performed on pelagic species groups there is only one that describes the nature of the species association at a synecological level. Lawson (1977) found niche separation of copepods along body size and feeding morphology axes. Similar species were separated geographically. It would be extremely interesting to perform similar analyses on co-occurring myctophid species because of their seemingly similar morphology.

The results of this study question the existence of

structured communities in mesopelagic fishes. Groups of species are separable by some techniques, but the use of varied analyses present results that are best interpreted as a gradation between faunas. The fact that few species share similar distribution patterns suggests that encounters between species are unpredictable, so species interactions may be limited. Stochasticity, as defined by Grossman (1982) and Grossman *et al.* (1982), may be introduced because the organisms a fish encounters are unpredictable.

To continue searching for recurrent groups of species through various taxonomic groups and in various areas is probably fruitless. As Strong (1983) observes, "The meaning of general patterns is an historically important approach to community ecology, but an approach that I fear now bears relatively little promise for understanding mechanisms." The mechanisms and extent of interactions between organisms in pelagic environments are not well known. What is needed are detailed small scale studies of species interactions rather than statistical techniques applied over wide ranges. If these interactions are inconsequential then communities *per se* do not exist and species assemblages are random associations. The species

are present because of the immediate hydrographic history of the area and the individual species' reactions to their local environment.

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TABLE 1: Station data for collections used in this study.

Sample	Cruise (#)	Lat. (N)	Long. (W)	Date (D/M/Y)	Time (local)	Depth (m)	Temp. 200 (°C)	Gear*
1	GA51	45 00	48 28	20/05/81	0730	512	2.2	EMT
2	GA51	44 59	48 25	20/05/81	0925	915	2.2	EMT
3	GA51	45 00	47 28	20/05/81	1447	457	4.5	EMT
4	GA51	44 59	47 27	20/05/81	1617	1010	4.5	EMT
5	GA51	45 00	46 29	20/05/81	2045	489	4.1	EMT
6	GA51	45 00	46 26	20/05/81	2200	1018	4.1	EMT
7	GA51	45 01	45 30	21/05/81	0740	517	5.1	EMT
8	GA51	45 02	45 30	21/05/81	0903	1132	5.1	EMT
9	GA51	45 01	44 31	21/05/81	1456	457	5.2	EMT
10	GA51	45 01	44 32	21/05/81	1615	775	5.2	EMT
11	GA51	45 04	43 31	21/05/81	2220	409	14.5	EMT
12	GA62	41 27	56 01	21/02/82	2128	100	12.8	EMT
13	GA62	41 17	56 03	22/02/82	0210	100	12.0	EMT
14	GA62	40 48	56 00	22/02/82	2050	100	11.9	EMT
15	GA62	40 38	56 00	23/02/82	0133	100	12.2	EMT
16	GA62	40 27	56 08	23/02/82	0523	100	13.3	EMT
17	GA62	39 47	56 00	25/02/82	0145	100	14.2	SBT
18	GA62	39 18	56 01	28/02/82	0100	100	14.5	SBT
19	GA62	39 08	56 01	28/02/82	0405	100	14.3	SBT
20	GA62	37 21	55 00	01/03/82	2000	100	16.9	SBT
21	GA62	37 41	55 00	02/03/82	0040	100	17.0	SBT
22	GA62	38 01	55 00	02/03/82	0514	100	17.0	SBT
23	GA62	39 00	54 00	03/03/82	2131	100	17.3	SBT
24	GA62	38 40	54 00	04/03/82	0235	100	17.0	SBT
25	GA62	37 41	53 00	05/03/82	2348	100	16.7	SBT
26	GA62	38 00	53 00	05/03/82	0428	100	16.7	SBT
27	GA62	39 21	53 00	05/03/82	2152	100	16.9	SBT
28	GA62	39 40	53 00	06/03/82	0220	100	17.4	SBT
29	GA62	40 10	53 00	06/03/82	2335	100	13.7	SBT

TABLE 1: continued

30	GA62	40 31	53 00	07/03/82	0339	100	13.8	SBT
31	GA62	41 20	53 00	07/03/82	2212	100	12.3	SBT
32	BE03	40 54	60 05	28/03/79	1421	500	13.6	EMT
33	BE03	40 51	59 21	29/03/79	0245	500	14.6	EMT
34	BE03	39 40	58 31	30/03/79	1455	500	17.9	EMT
35	BE03	39 01	56 09	31/03/79	1018	500	17.4	EMT
36	BE03	39 44	56 59	01/04/79	0114	100	17.9	EMT
37	BE03	39 44	56 59	01/04/79	2343	500	17.9	EMT
38	BE03	39 44	56 59	01/04/79	0711	500	17.9	EMT
39	BE03	39 44	56 59	01/04/79	1055	500	17.9	EMT
40	BE03	39 43	56 58	01/04/79	1455	500	17.9	EMT
41	BE03	39 44	56 59	01/04/79	1859	500	17.9	EMT
42	BE03	41 08	58 38	03/04/79	1010	500	13.8	EMT
43	BE03	41 48	59 28	03/04/79	2211	500	13.6	EMT
44	BE03	42 27	58 27	04/04/79	1722	500	11.8	EMT
45	BE03	41 44	57 38	05/04/79	0705	500	13.4	EMT
46	BE03	41 01	56 48	05/04/79	2106	500	13.8	EMT
47	BE03	40 17	55 58	06/04/79	1131	500	13.4	EMT
48	BE03	39 32	55 06	06/04/79	2226	100	14.1	EMT
49	BE03	39 32	55 06	07/04/79	0027	500	14.1	EMT
50	BE03	38 49	54 18	07/04/79	1323	500	14.1	EMT
51	BE03	38 05	53 28	07/04/79	2345	500	17.0	EMT
52	BE03	39 26	53 13	08/04/79	2005	500	15.7	EMT
53	BE03	40 12	54 06	09/04/79	1000	500	12.3	EMT
54	BE03	40 57	55 00	09/04/79	2240	500	11.8	EMT
55	BE03	41 40	55 49	10/04/79	0940	500	11.4	EMT
56	BE03	42 02	56 15	10/04/79	2115	500	11.1	EMT
57	BE03	42 22	56 40	11/04/79	0756	500	----	EMT
58	BE03	43 40	56 31	12/04/79	0222	500	9.3	EMT
59	BE03	43 06	55 55	12/04/79	1148	500	5.7	EMT
60	BE03	42 12	54 55	12/04/79	2335	100	10.2	EMT
61	BE03	42 12	54 55	13/04/79	0143	500	10.2	EMT
62	BE03	41 29	54 06	13/04/79	1355	500	12.2	EMT

TABLE 1: continued

63	BE04	41 12	49 20	27/04/79	0240	100	8.2	EMT
64	BE04	42 07	46 22	30/04/79	0238	100	14.7	EMT
65	BE04	44 11	45 57	01/05/79	1905	100	7.7	EMT
66	BE04	44 16	45 21	02/05/79	0210	100	8.2	EMT
67	BE04	44 40	47 53	02/05/79	1937	100	5.7	EMT
68	BE04	45 36	44 35	03/05/79	1919	100	9.0	EMT
69	BE04	45 06	43 58	04/05/79	0203	100	11.0	EMT

* EMT = Engels midwater trawl
  SBT = Sputnik bottom trawl

# GA = Gadus Atlantica
  BE = Belogorsk

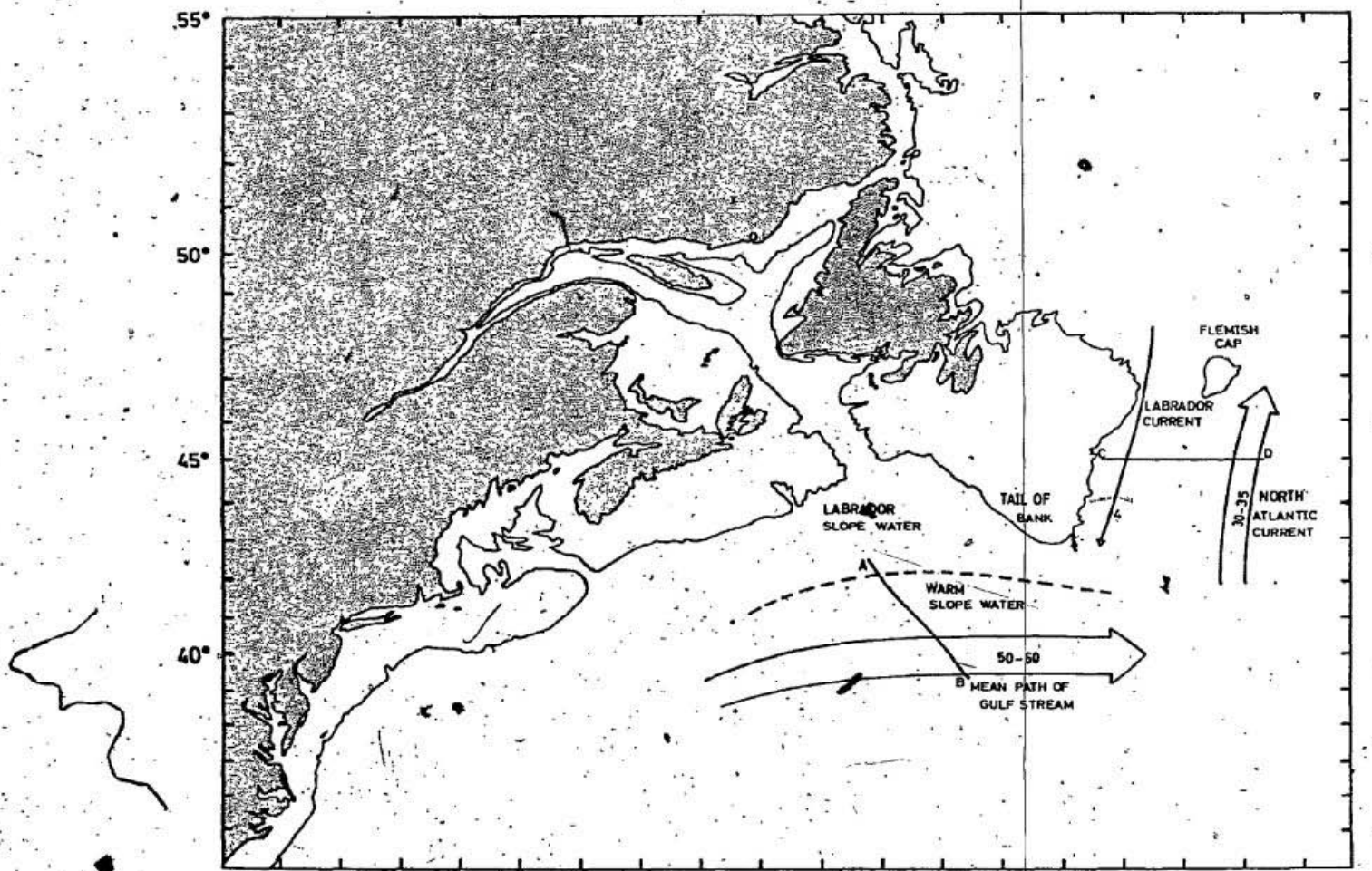
TABLE 2. Recurrent groups of species.

Group 1	Group 2
Hygophum benoiti	*Benthosema glaciale*
Bolinichthys indicus	*Chauliodus sloani*
Lampanyctus photonotus	*Ceratoscopelus maderensis*
Associated:	Associated:
Bathylagus compsus	*Symbolophorus veranyi*

TABLE 3. Number of species identified in the major families for each of the three areas.

Family	Number of Species		
	Newfoundland Basin	Slope Water	Gulf Stream
Myctophidae	14	39	29
Bathylagidae	1	4	3
Stomiatidae	1	1	1
Chauliodontidae	1	2	1
Gonostomatidae	3	13	5
Melamphaidae	3	6	1
Melanostomiatidae	1	4	5
Sternoptychidae	2	5	2
Scopelosauridae	0	2	1
Diretmidae	1	1	1
Paralepididae	1	1	1
Total	28	79	50

FIGURE 1. Generalized flow of currents in the study area. Thickness of arrows and associated numbers are relative volume transport (in Sverdrups). The dashed line separates the two sections of the Slope Water. Composite drawing from Mann (1967), Gatien (1976), Worthington (1976), and Petrie and Anderson (1983). Transects A-B and C-D are used to illustrate hydrographic properties during sampling. Depth contour is 180 m.


55°
50°
45°
40°
70°
60°
50°
FLEMISH CAP
LABRADOR CURRENT
D
TAIL OF BANK
LABRADOR SLOPE WATER
NORTH ATLANTIC CURRENT
30-35
A
WARM SLOPE WATER
50-50
B
MEAN PATH OF GULF STREAM

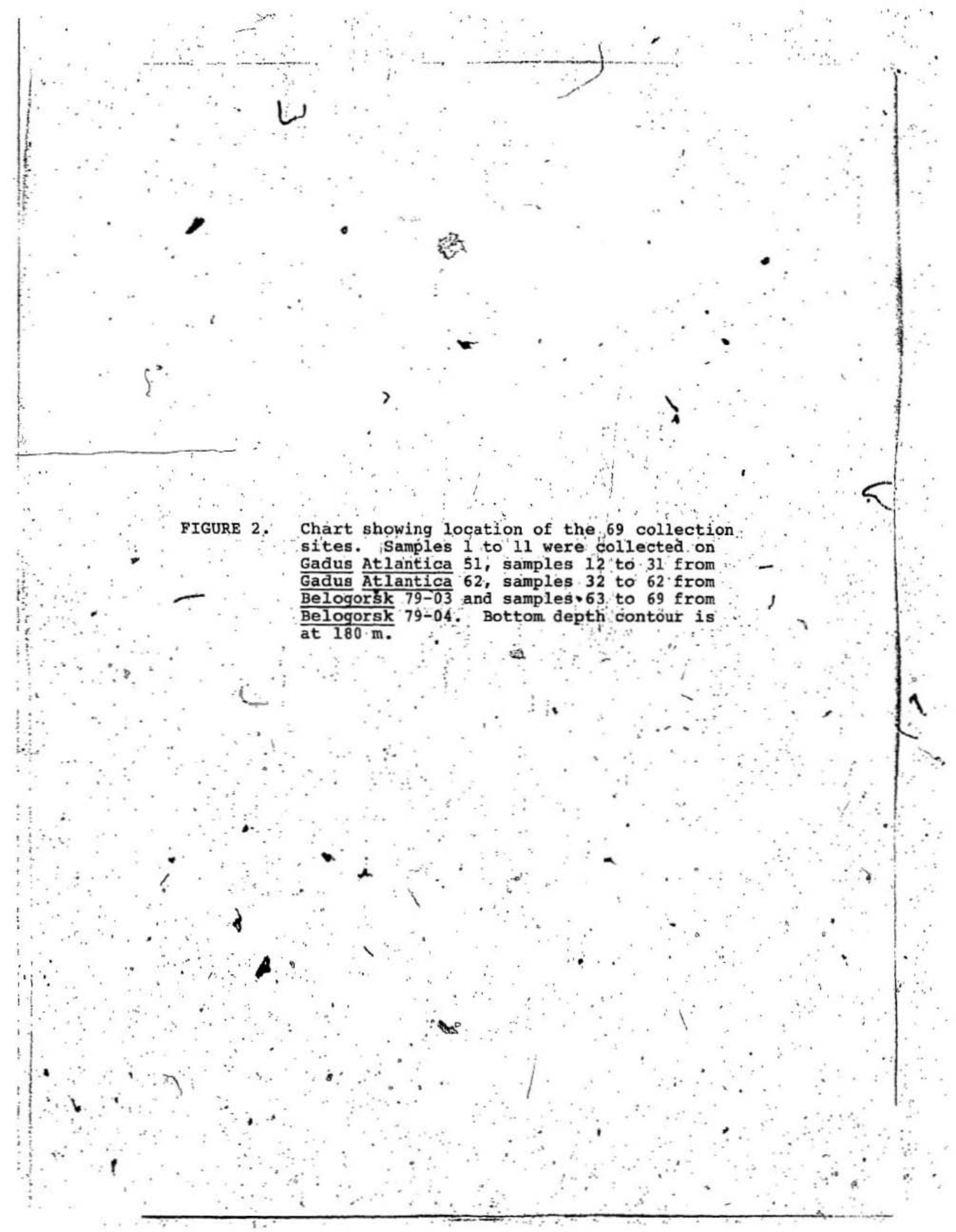


FIGURE 2. Chart showing location of the 69 collection sites. Samples 1 to 11 were collected on Gadus Atlantica 51, samples 12 to 31 from Gadus Atlantica 62, samples 32 to 62 from Belogorsk 79-03 and samples 63 to 69 from Belogorsk 79-04. Bottom depth contour is at 180 m.

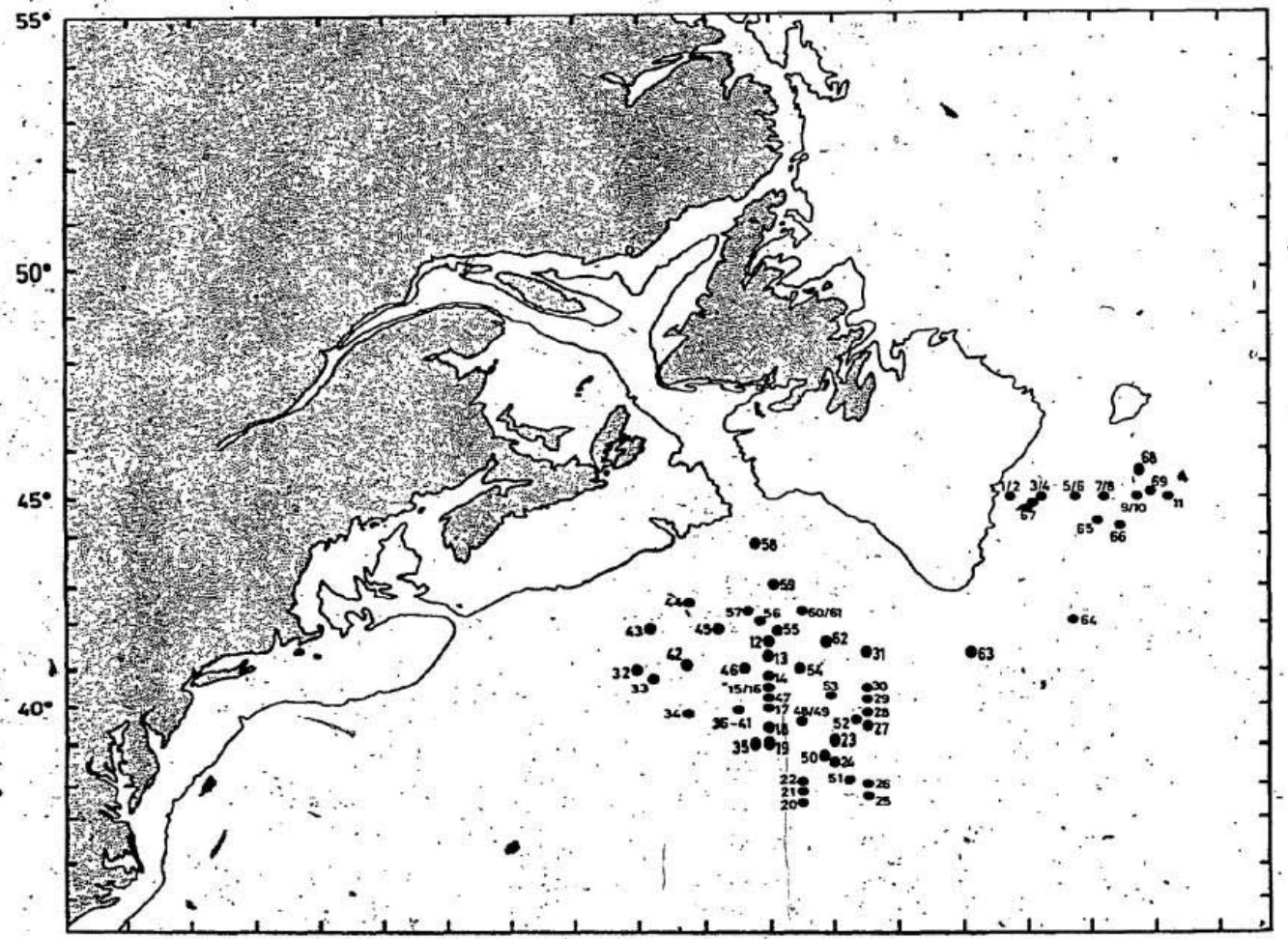

55°
50°
45°
40°
70°
60°
50°
1/2
3/4
5/6
7/8
9/10
11
68
69
4
67
65
66
64
58
59
57
56
60/61
55
63
62
31
54
53
30
29
28
27
48/49
52
23
50
24
51
26
25
22
21
20
19
18
17
16
15
14
13
12
46
45
43
42
32
33
34
35
36-41

FIGURE 3. Temperature profile along transect A-B from Belogorsk 79-03. Contour interval is 1°C.

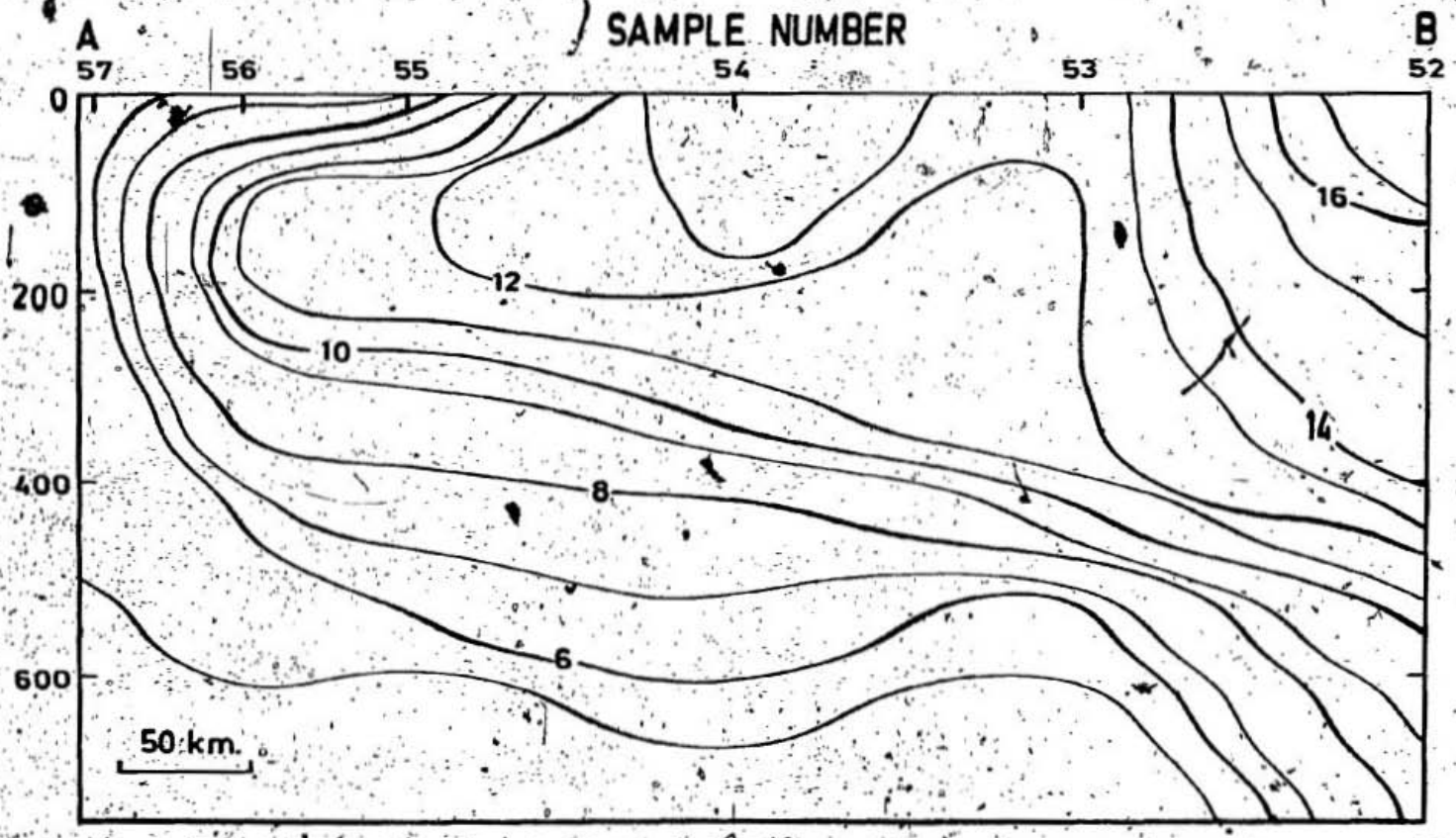

A
SAMPLE NUMBER
B
57
56
55
54
53
52
0
200
400
600
DEPTH (m)
16
12
10
14
8
6
50 km.

FIGURE 4. Salinity profile along transect A-B from Belogorsk 79-03. Contour interval is 0.2 ppt.

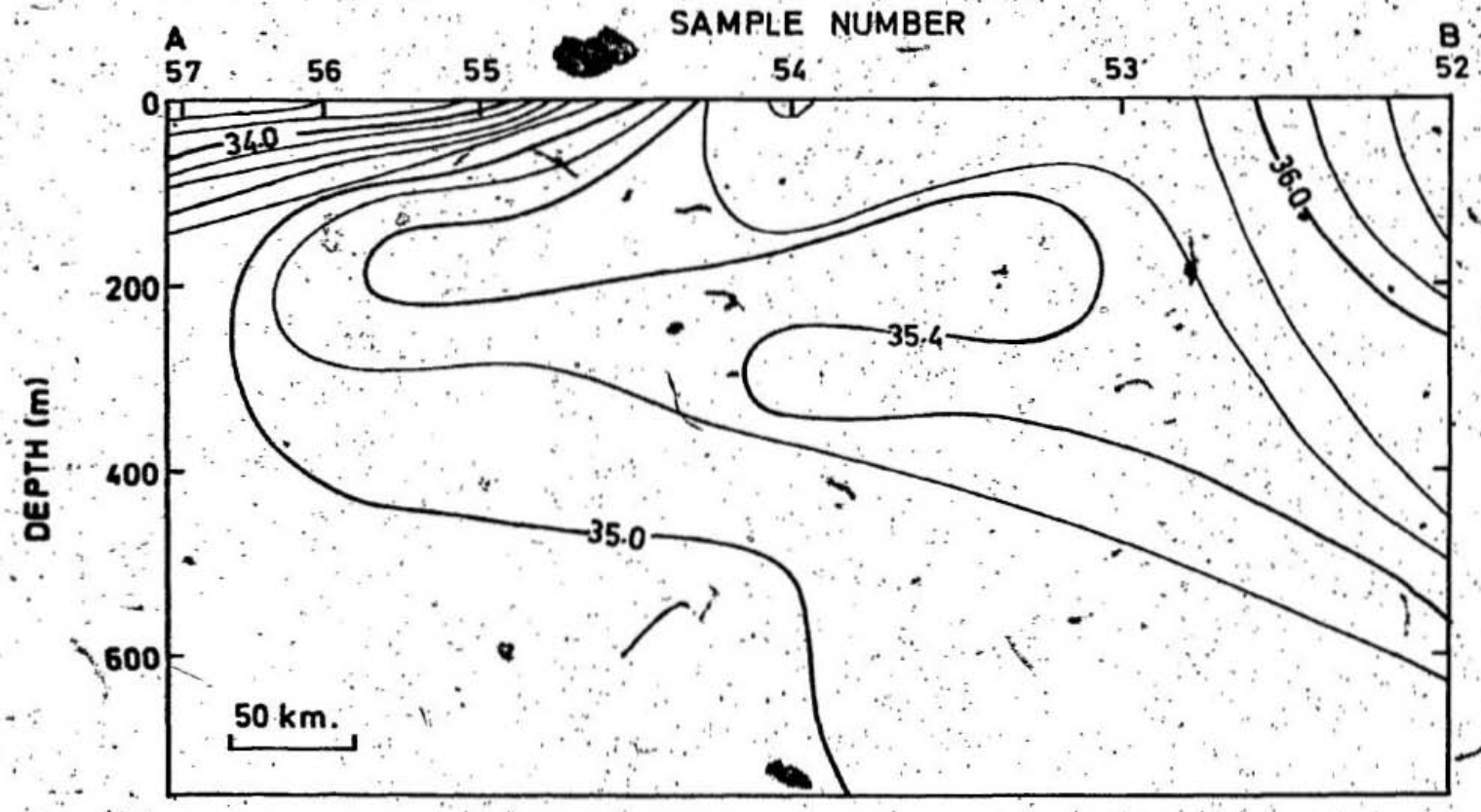

SAMPLE NUMBER
A
B
57
56
55
54
53
52
0
200
400
600
DEPTH (m)
34.0
35.4
35.0
36.0
50 km.

FIGURE 5. Temperature profile along transect C-D from *Gadus Atlantica* 51: Contour interv
is 2°C.

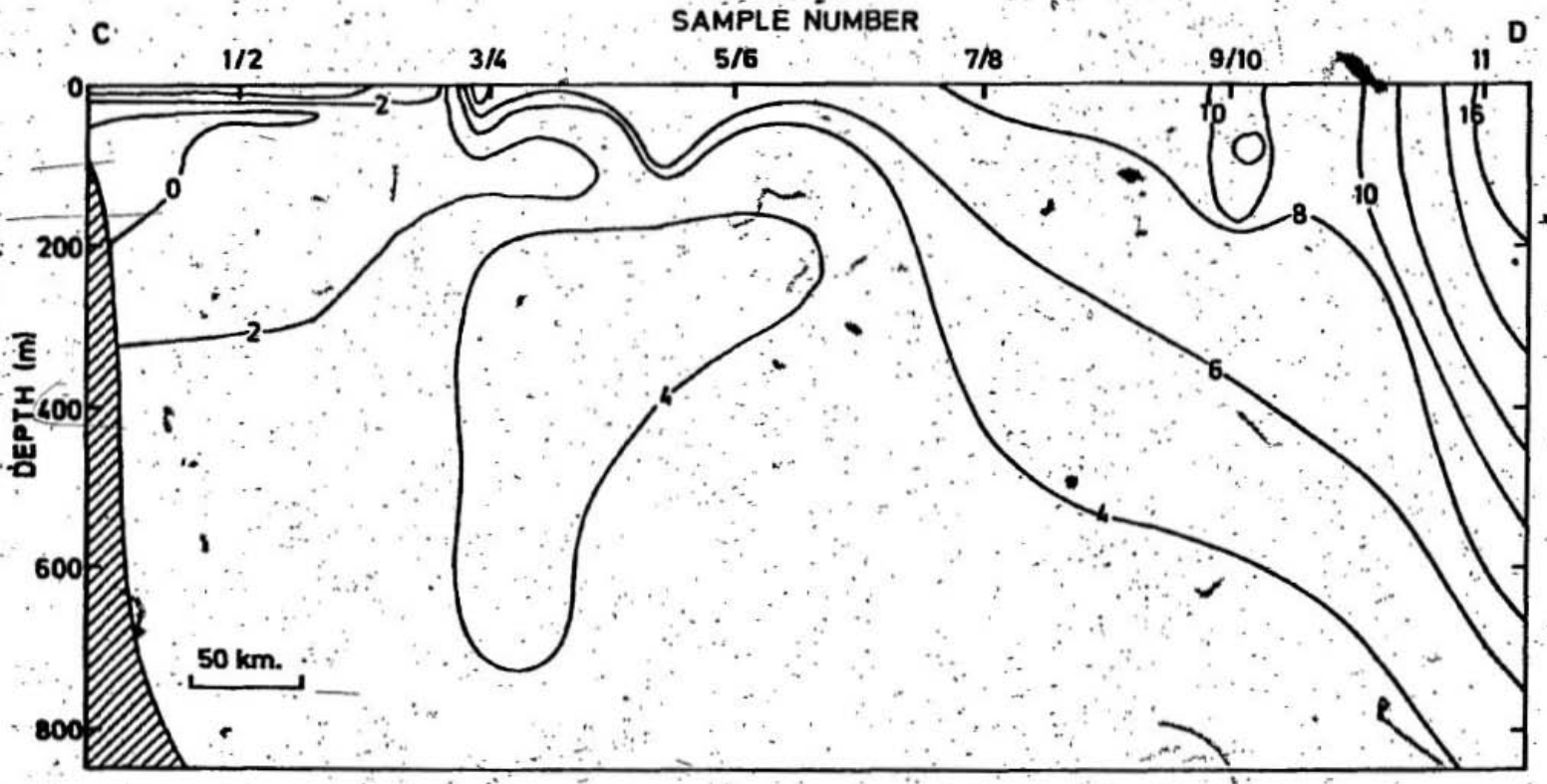
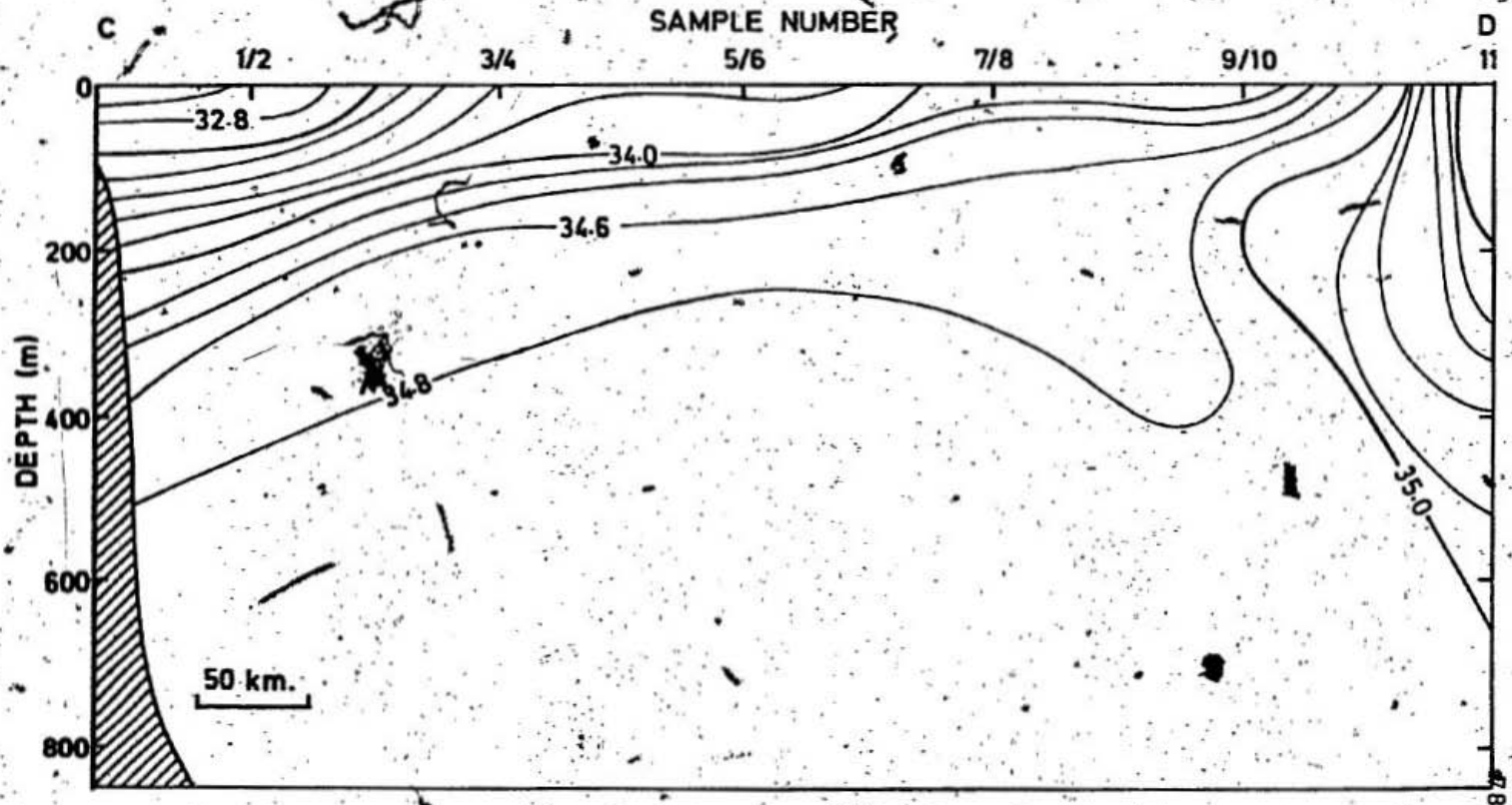

C
SAMPLE NUMBER
1/2
3/4
5/6
7/8
9/10
11
D
0
200
400
600
800
DEPTH (m)
50 km.
0
2
4
6
8
10
16

FIGURE 6. Salinity profile along transect C-D from Gadus Atlantica 51. Contour interval is 0.2 ppt.


C
SAMPLE NUMBER
D
1/2
3/4
5/6
7/8
9/10
11
0
200
400
600
800
DEPTH (m)
32·8
34·0
34·6
34·8
35·0
50 km.

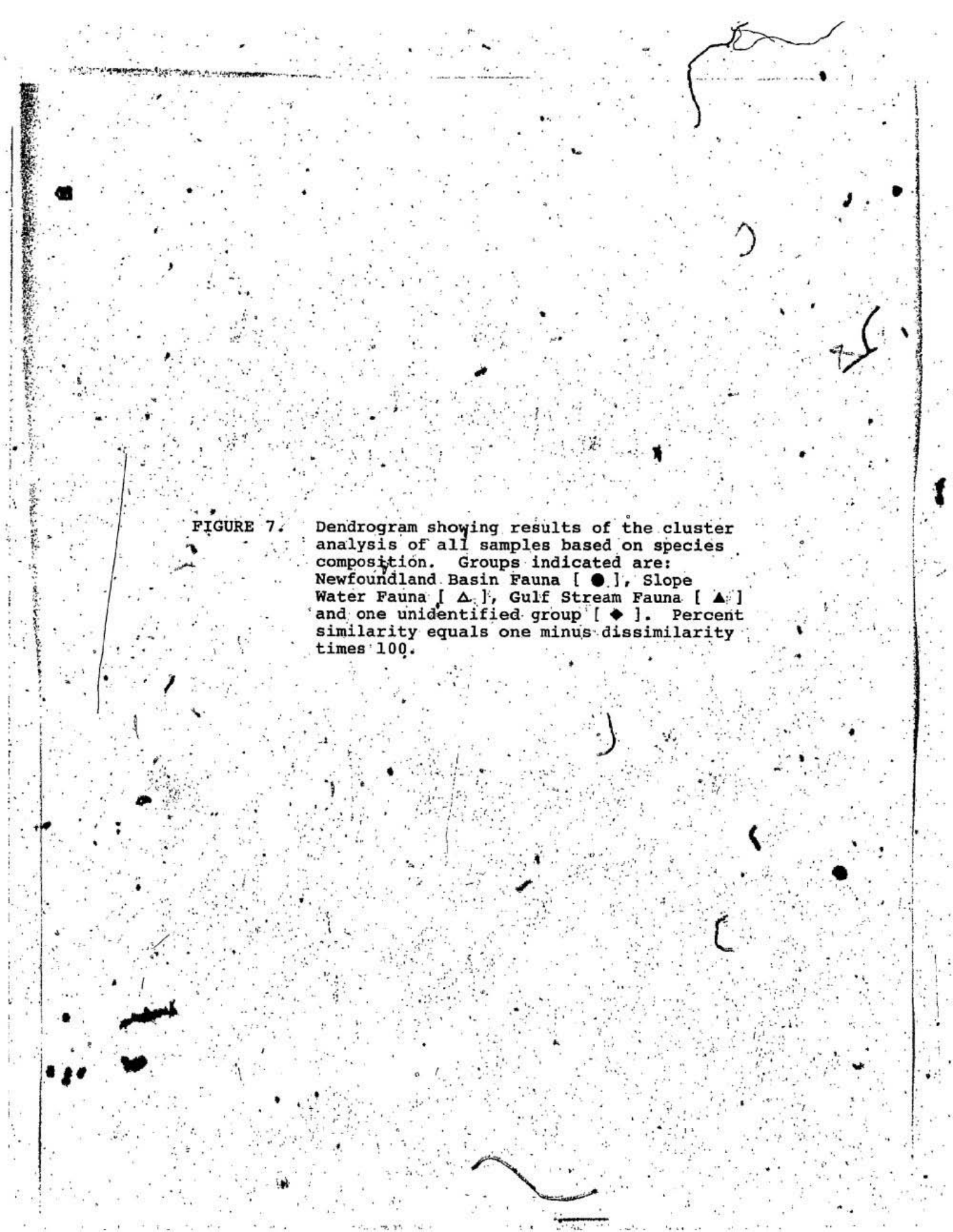


FIGURE 7. Dendrogram showing results of the cluster analysis of all samples based on species composition. Groups indicated are: Newfoundland Basin Fauna [●], Slope Water Fauna [△], Gulf Stream Fauna [▲] and one unidentified group [◆]. Percent similarity equals one minus dissimilarity times 100.

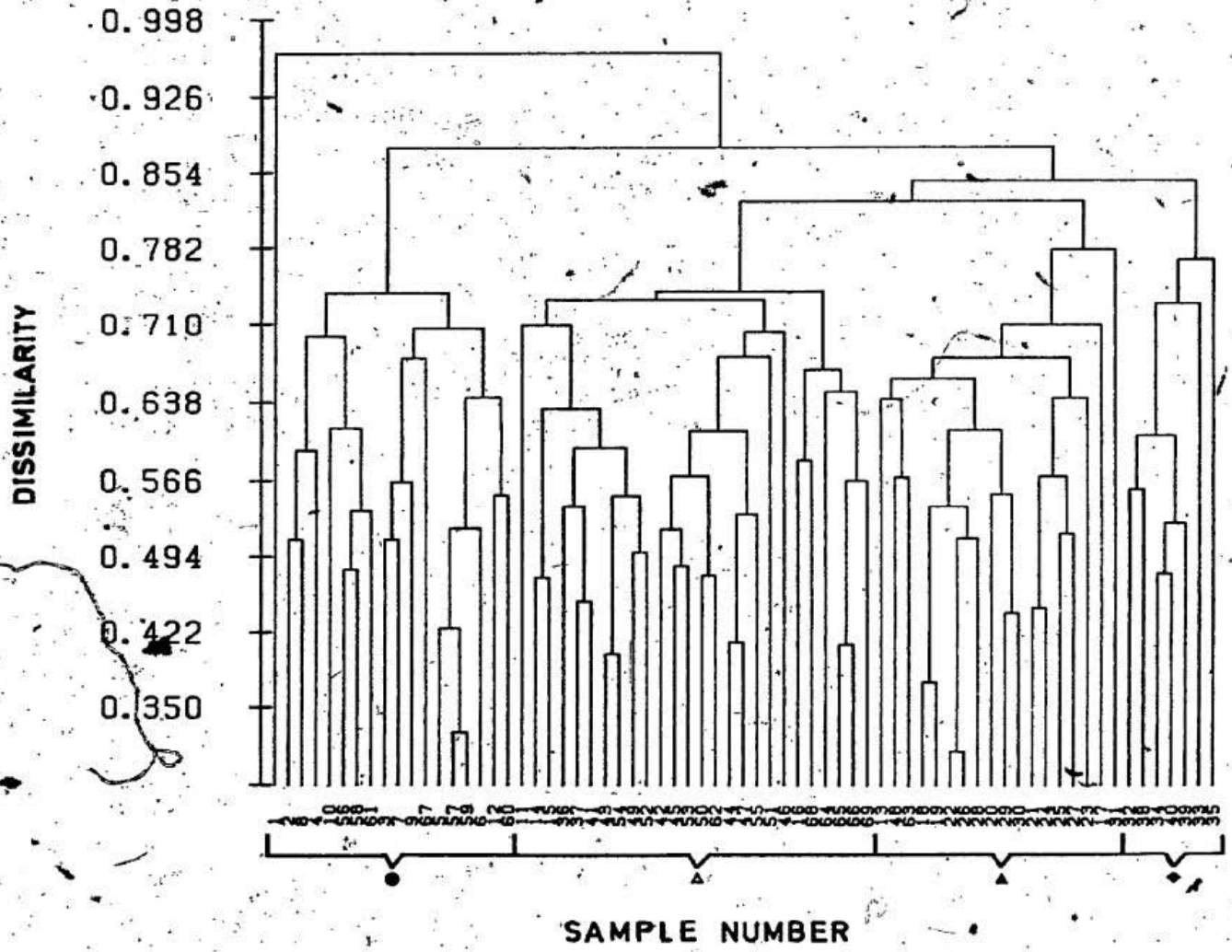
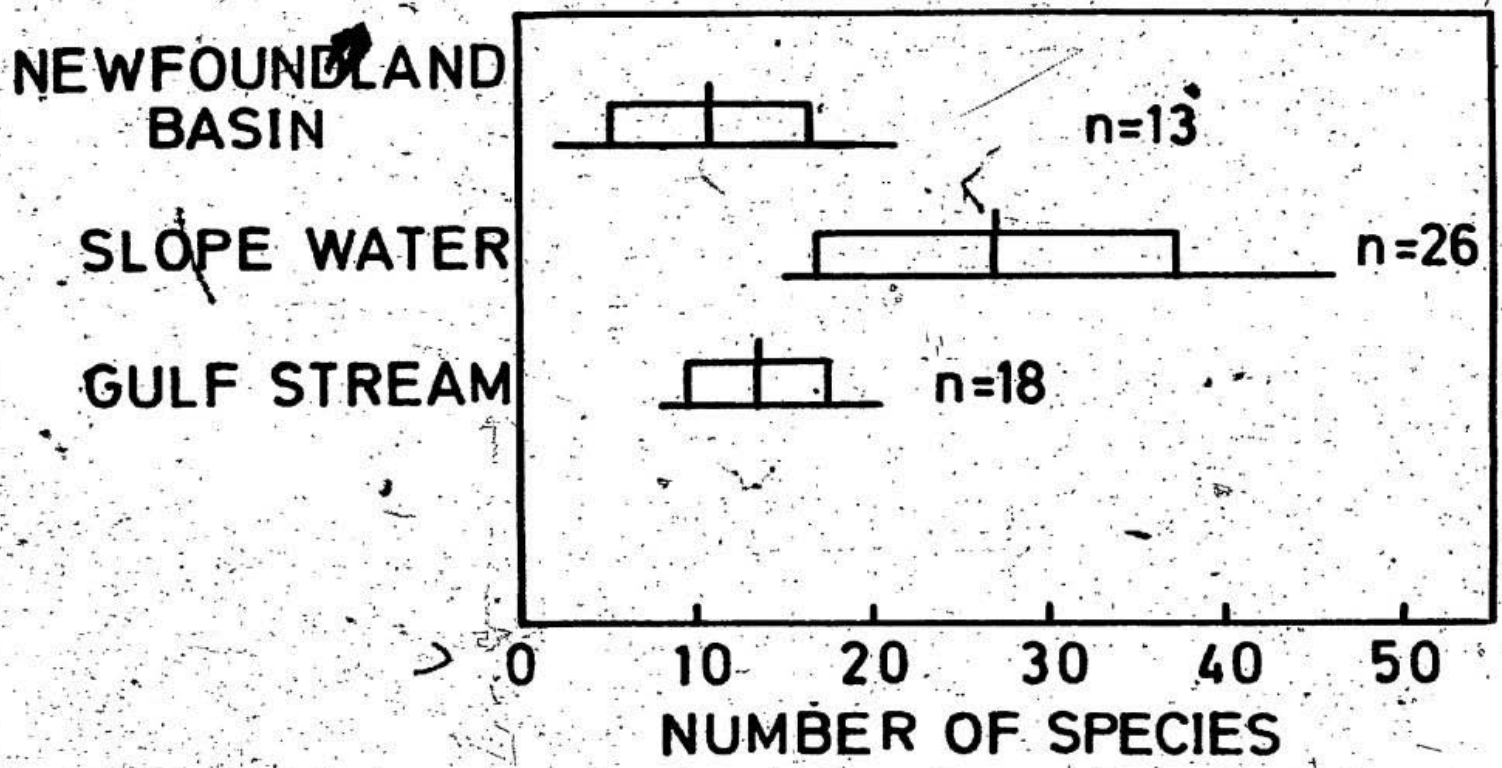

0.998
0.926
0.854
0.782
0.710
0.638
0.566
0.494
0.422
0.350
DISSIMILARITY
SAMPLE NUMBER

FIGURE 8. Mean number of species for each of the three faunas. One standard deviation on either side of the mean and the range are shown. For comparative purposes only samples from depths of 500 m or less were used. The number of samples (n) from each fauna is indicated.


NEWFOUNDLAND BASIN
SLOPE WATER
GULF STREAM
n=13
n=26
n=18
0
10
20
30
40
50
NUMBER OF SPECIES

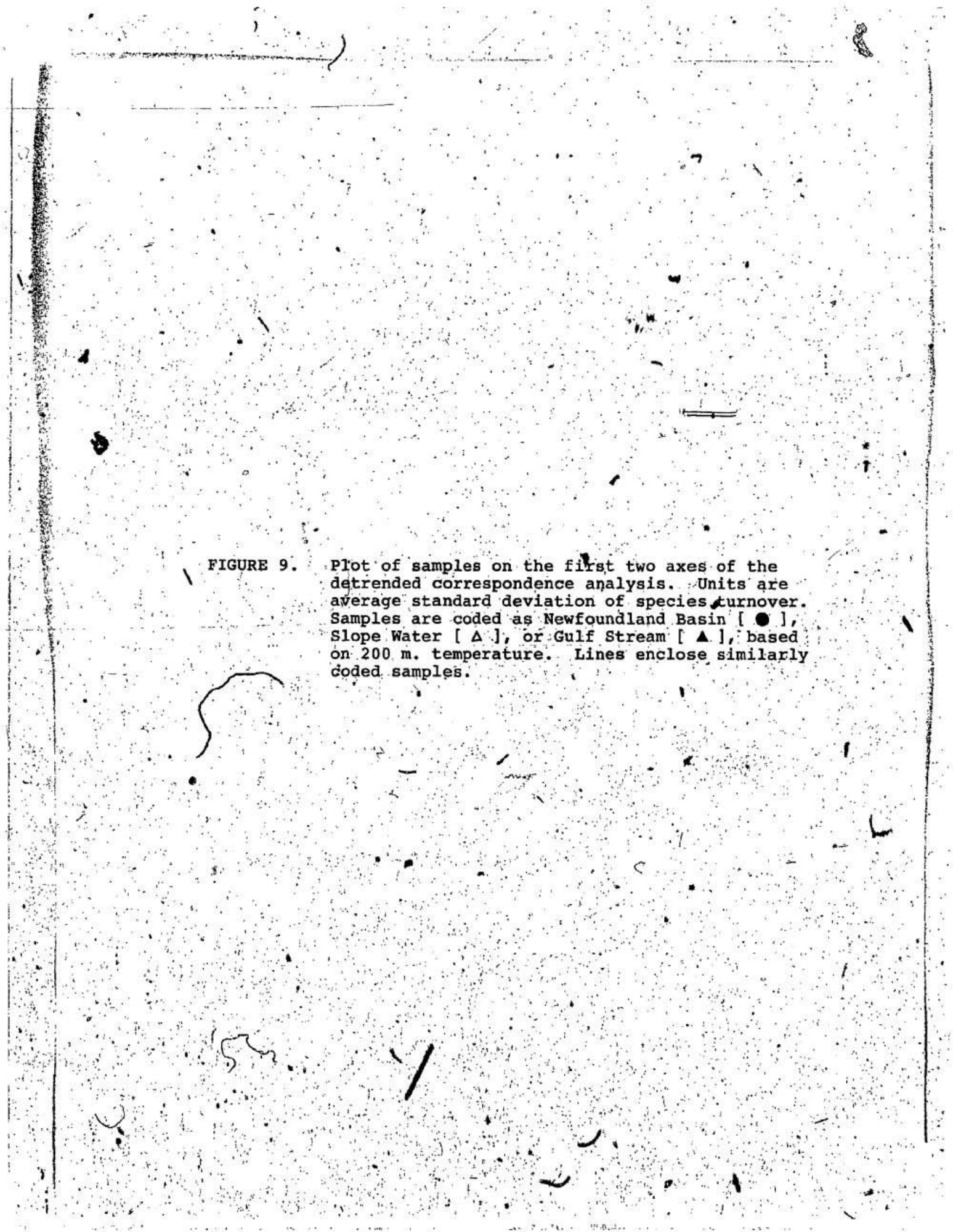
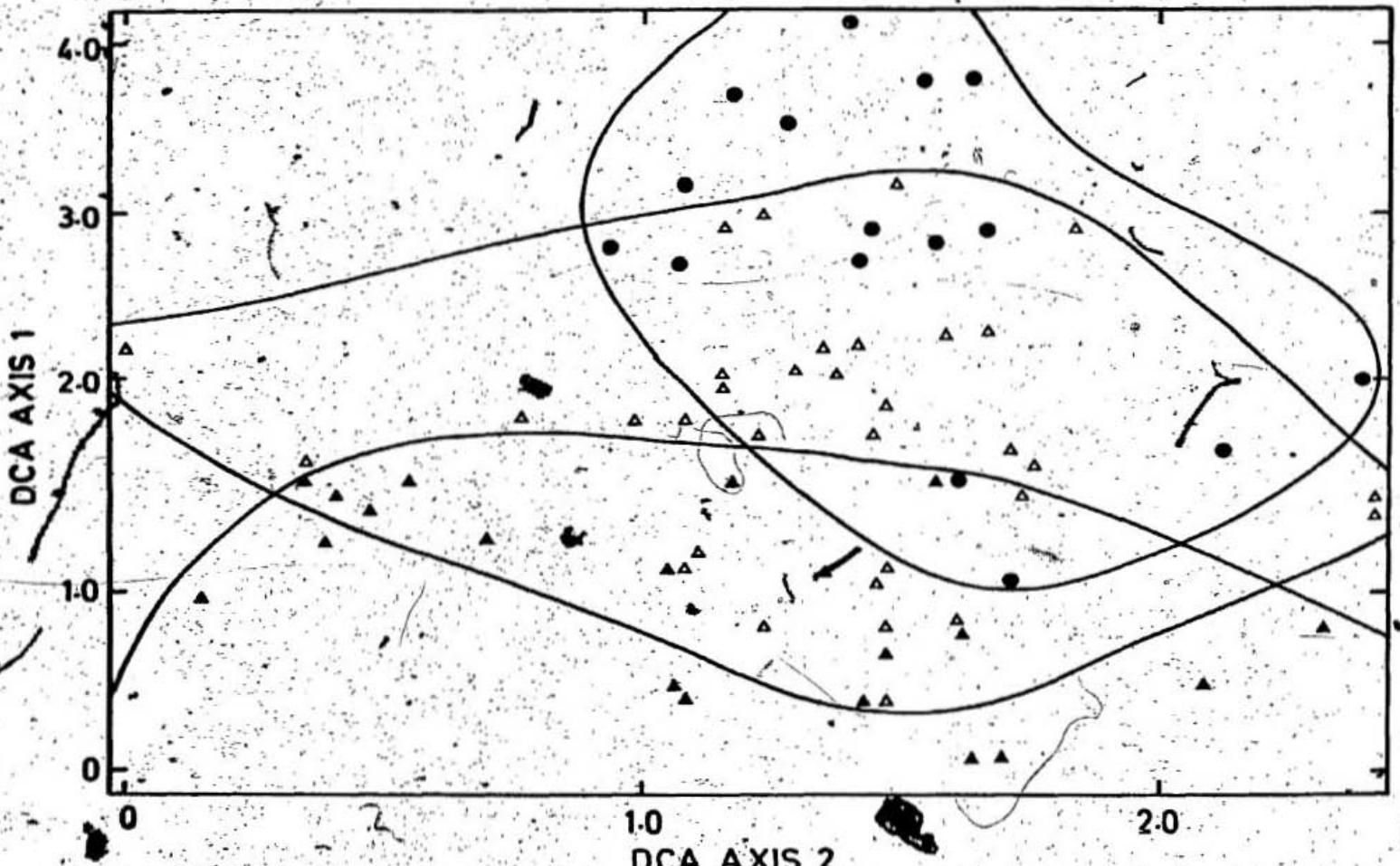


FIGURE 9. Plot of samples on the first two axes of the detrended correspondence analysis. Units are average standard deviation of species turnover. Samples are coded as Newfoundland Basin [●], Slope Water [Δ], or Gulf Stream [▲], based on 200 m. temperature. Lines enclose similarly coded samples.


4·0
3·0
2·0
1·0
0
DCA AXIS 1
0
1·0
2·0
DCA AXIS 2

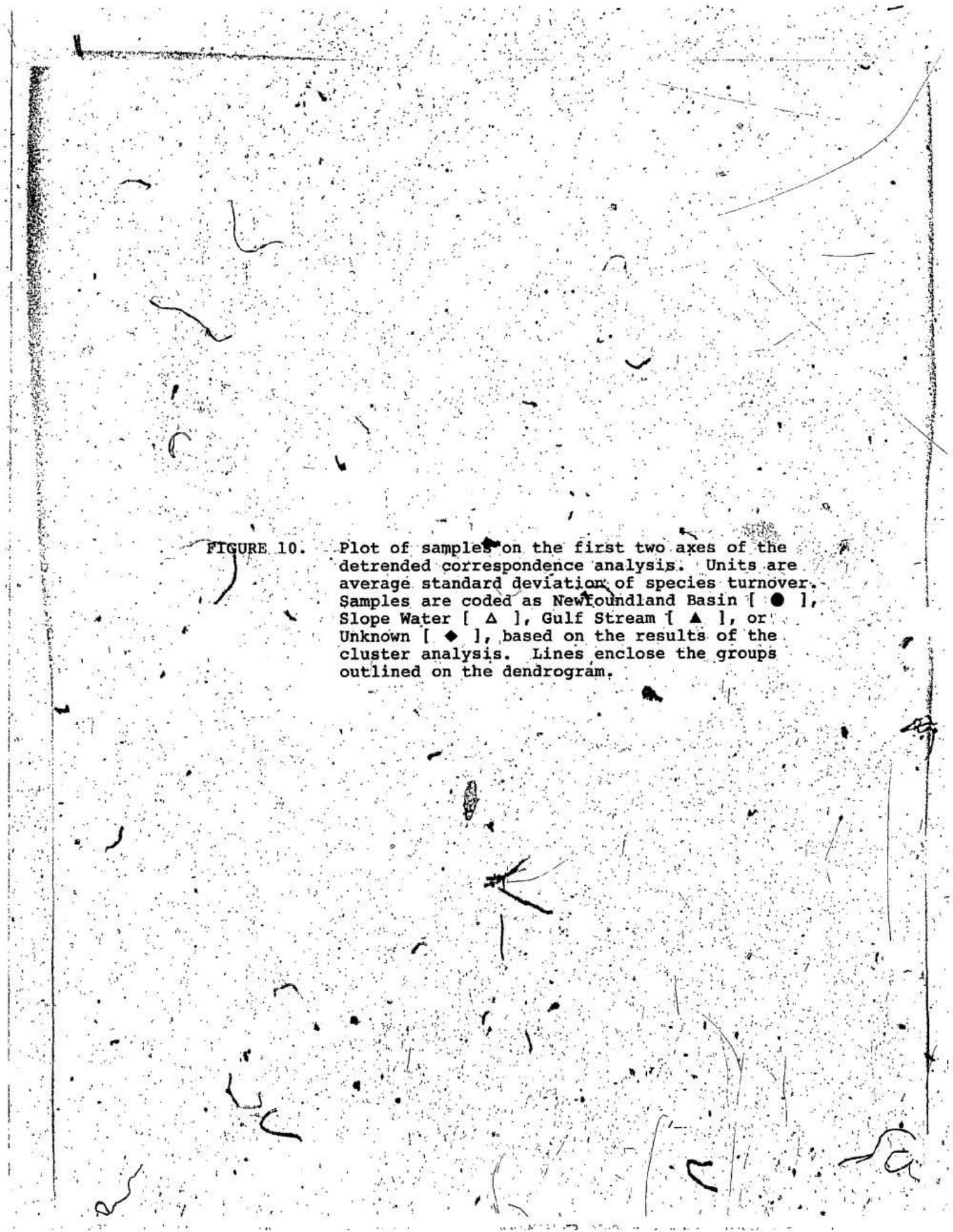
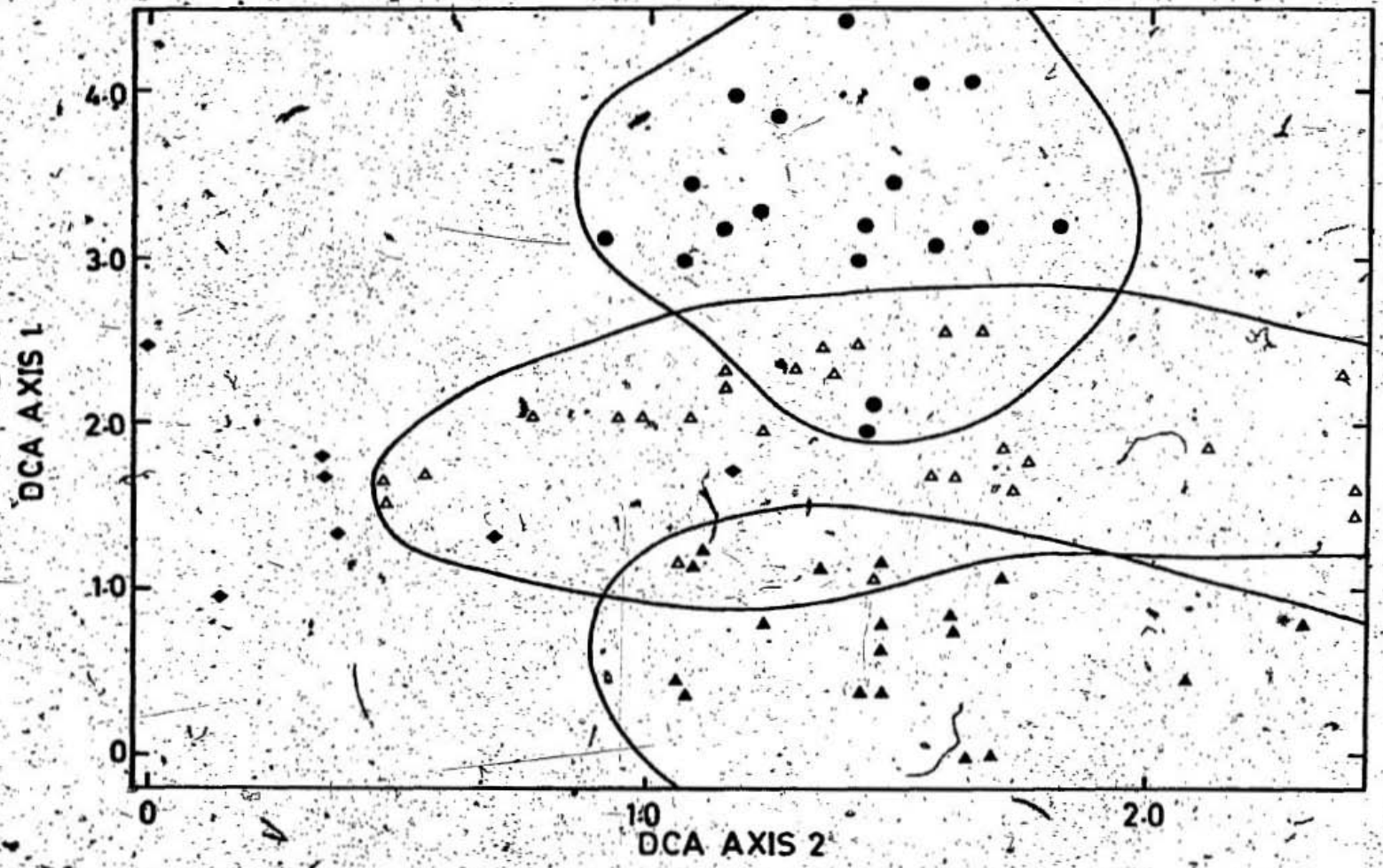


FIGURE 10. Plot of samples on the first two axes of the detrended correspondence analysis. Units are average standard deviation of species turnover. Samples are coded as Newfoundland Basin [●], Slope Water [△], Gulf Stream [▲], or Unknown [◆], based on the results of the cluster analysis. Lines enclose the groups outlined on the dendrogram.


4·0
3·0
2·0
1·0
0
DCA AXIS 1
0
1·0
2·0
DCA AXIS 2

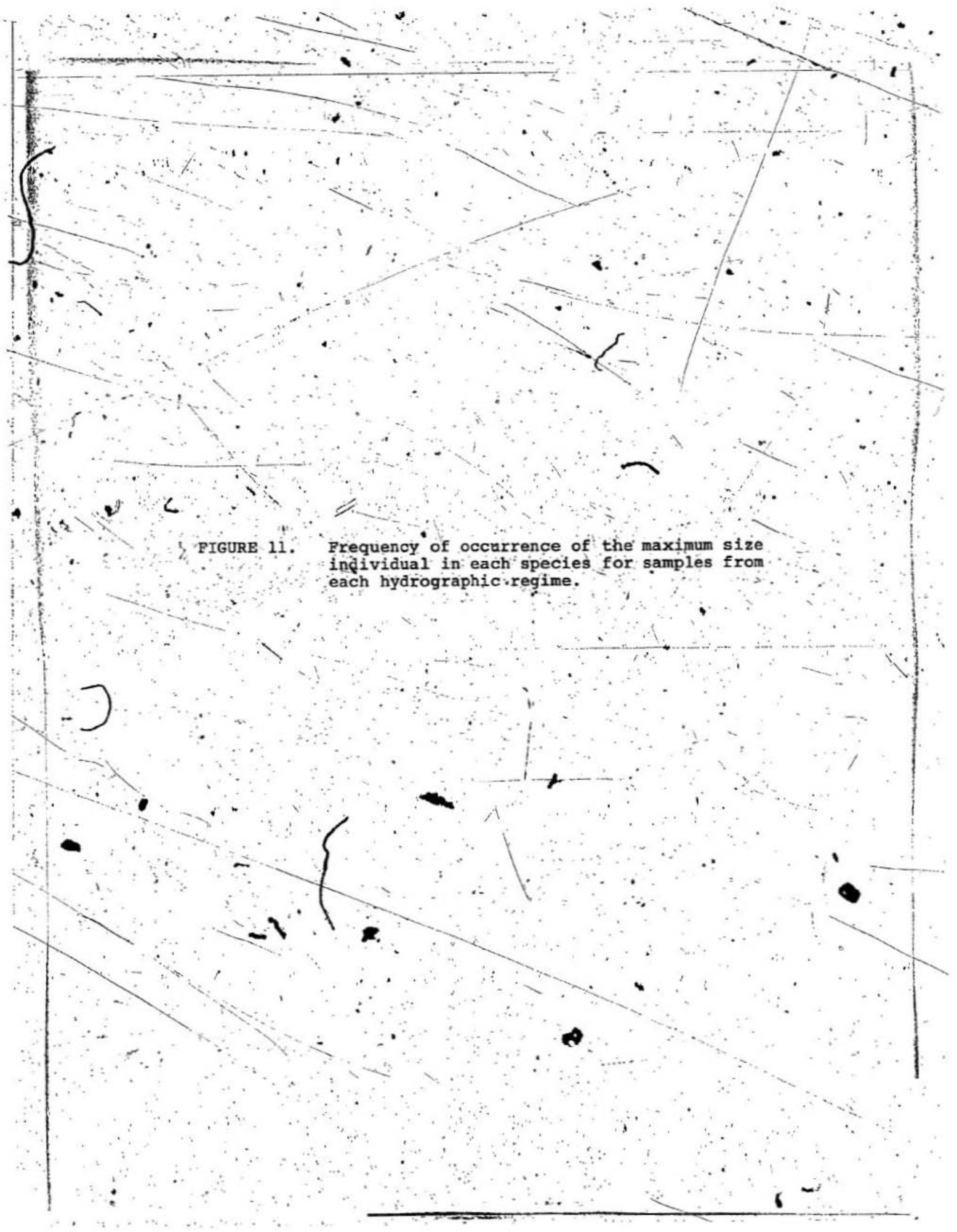


FIGURE 11. Frequency of occurrence of the maximum size individual in each species for samples from each hydrographic regime.

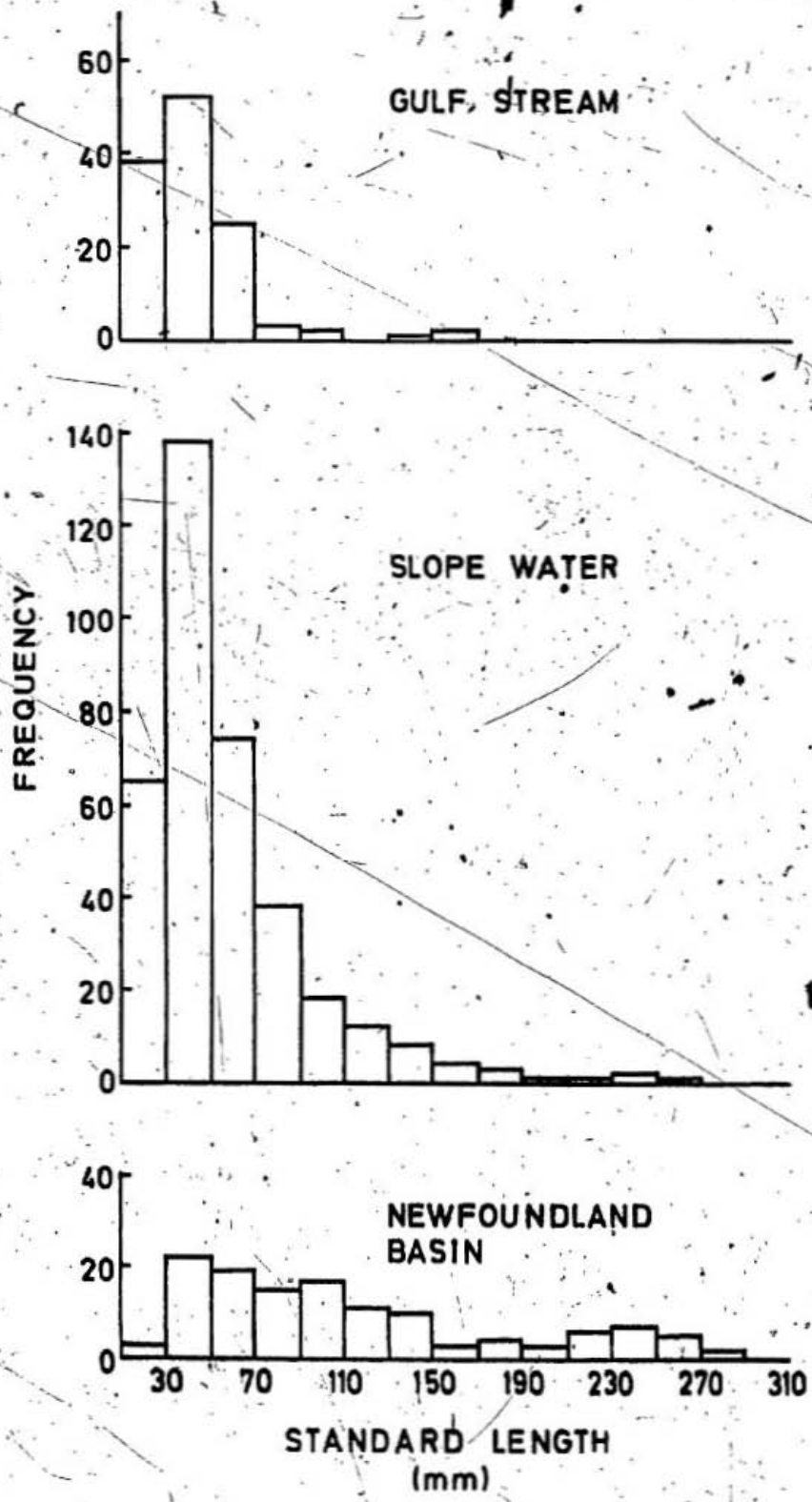
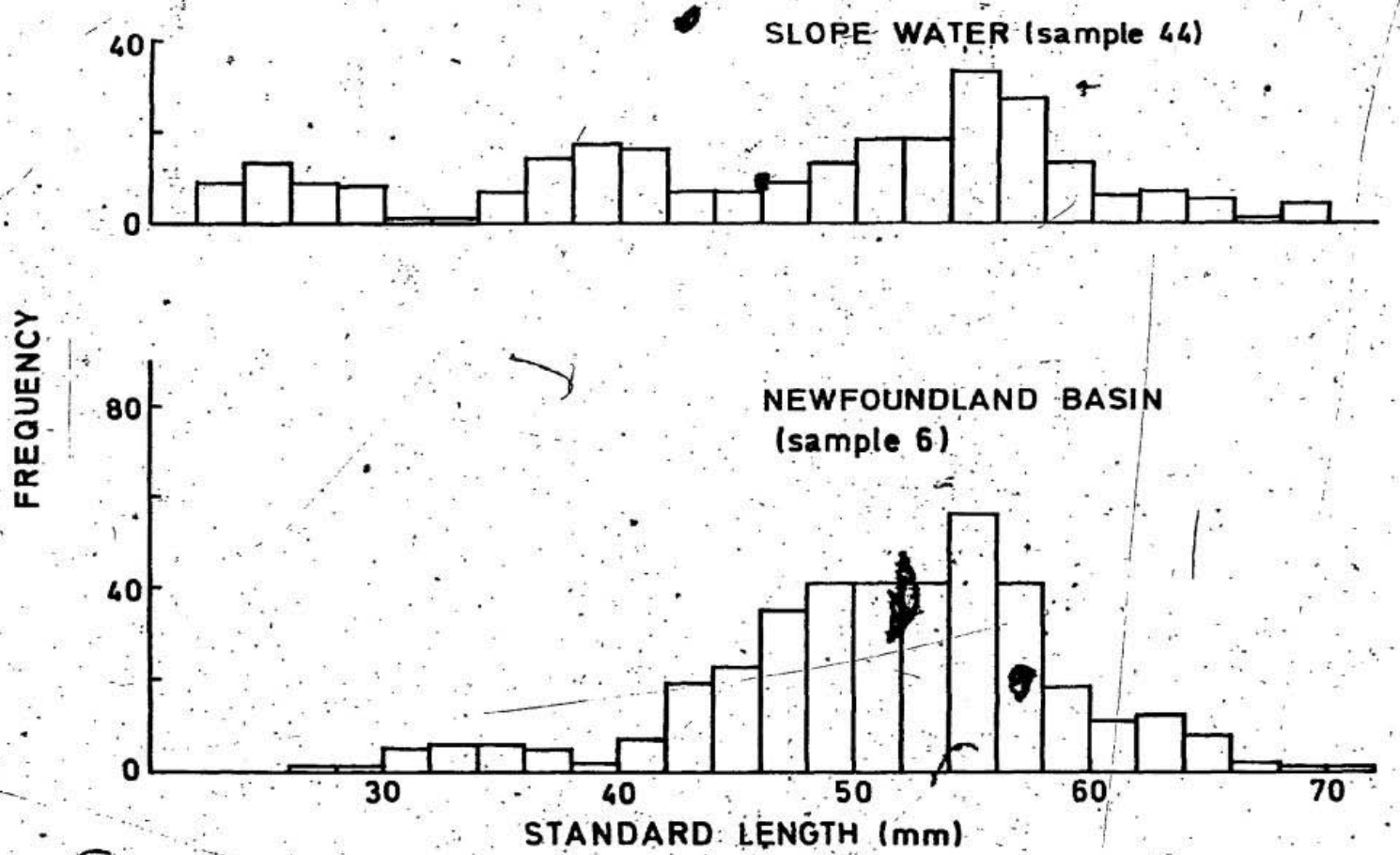

GULF STREAM
SLOPE WATER
NEWFOUNDLAND BASIN
FREQUENCY
0
20
40
60
80
100
120
140
30
70
110
150
190
230
270
310
STANDARD LENGTH (mm)

FIGURE 12. Representative length frequency of Benthosema glaciale for samples from the Slope Water and the Newfoundland Basin.


SLOPE WATER (sample 44)
40
0
FREQUENCY
NEWFOUNDLAND BASIN
(sample 6)
80
40
0
30
40
50
60
70
STANDARD LENGTH (mm)

APPENDIX A

Fishes of the Newfoundland Basin

Family Species	sample no. (no. of individuals, weight (gm.))
Alepocephalidae	
Xenodermichthys copei (Vaillant) 1888	5(1,4)
Anoplogasteridae	
Anoplogaster cornuta (Valenciennes 1833)	4(1,78), 8(1,78)
Astronesthidae	
Borostomias antarcticus (Lonnberg 1905)	2(4,15), 4(1,4), 5(1,40), 6(3,192), 8(1,55)
Bathylagidae	
Bathylagus euryops Goode and Bean 1895	2(1,5), 4(66,330), 5(36,122), 6(32,484), 8(28,304), 9(47,84)
Caristiidae	
Caristius groenlandicus Jensen 1941	6(1,114)
Ceratiidae	
Ceratias holboelli Kroyer 1844	4(1,23)
Chauliodontidae	
Chauliodus sloani Bloch and Schneider 1801	2(7,115), 3(1,8), 4(15,334), 5(9,147), 6(16,382), 7(7,72), 8(8,110), 9(10,54), 10(28,537)

Appendix A: continued

Chiasmodontidae	
Chiasmodon niger Johnson 1863	5(1,7), 6(1,5), 10(1,3)
Derichthyidae	
Derichthys serpentinus Gill 1884	3(1,6), 6(1,9)
Diretmidae	
Diretmus argenteus Johnson 1863	4(1,38), 9(1,28), 10(6,262)
Eurypharyngidae	
Eurypharynx pelecanoides Vaillant 1882	8(1,46)
Gonostomatidae	
Cyclothone braueri Jesperson and Taning 1926	8(28,7)
Cyclothone microdon (Gunther) 1878	3(30,9), 6(19,13)
Gonostoma elongatum Gunther 1878	10(2,73)
Idiacanthidae	
Idiacanthus fasciola Peters 1877	6(1,2)
Linophrynidae	
Edriolychnus schmidti Regan 1925	4(1,4)
Macrouridae	
Nezumia bairdii (Goode and Bean) 1887	2(1,1)

Appendix A: continued

Malacosteidae	
Aristostomias lunifer Regan and Trewavas 1930	4(1,16)
Malacosteus niger Ayres 1848	4(4,42), 5(1,9), 6(5,204), 10(2,28)
Photostomias guernei Collett 1889	10(2,14)
Maurolicidae	
Maurolicus muelleri (Gmelin) 1788	9(1,1)
Melamphaidae	
Melamphaes microps Gunther 1887	4(1,1), 5(2,3), 8(1,22)
Poromitra megalops (Lutken 1877)	4(2,3)
Scopelogadus beanii (Gunther 1887)	5(1,25), 6(4,99), 8(3,87)
Melanostomiatidae	
Melanostomias spilorhynchus Regan and Trewavas 1930	10(3,204)
Myctophidae	
Benthosema glaciale (Reinhardt) 1837	1(250,524), 2(1623,2747), 3(81,184), 4(728,1420), 5(942,1813), 6(383,768), 7(403,855), 8(664,1289), 9(403,967), 10(166,416)
Bolinichthys indicus Nafpaktitis and Nafpaktitis 1969	4(1,1)
Bolinichthys photothorax (Parr) 1928	8(1,1)

Appendix A: continued

Bolinichthys supralateralis (Parr) 1928	10(1,8)
Ceratoscopelus maderensis Gunther 1864	6(1,2), 7(1,2), 9(10,17), 10(7,14)
Hygophum benoiti Cocco 1838	10(1,1)
Lampadena speculigera Goode and Bean 1896	4(1,28), 6(1,37), 8(1,29)
Lampanyctus ater Taning 1928	2(2,8), 4(4,40), 10(4,26)
Lampanyctus crocodilus (Risso) 1810	4(1,1), 5(1,1), 10(1,53)
Lampanyctus macdonaldi (Goode and Bean) 1896.	2(1,15), 4(3,39), 6(8,135), 8(4,78)
Lobianchia gemellarii (Cocco) 1838	10(4,64)
Myctophum punctatum Rafinesque 1810	5(1,3), 7(3,20), 8(2,9), 10(5,24)
Notoscopelus elongatus (Malm) 1861	2(1,14), 4(1,2), 10(1,12)
Protomyctophum arcticum (Lutken) 1892	1(1,1), 2(27,12), 3(1,1), 4(13,13), 5(78,75), 6(32,33), 7(14,13), 8(26,28), 9(5,5), 10(2,2)
Nemichthyidae	
Labichthys infans (Gunther 1878)	4(1,10)
Nemichthys scolopaceus Richardson 1848	2(1,14), 3(1,18), 8(1,17)
Oneirodidae	
Oneirodes flagellifer (Regan and Trewavas) 1932	8(1,0)
Oneirodes schmidti Bertelson 1951	6(1,62)

Appendix A: continued

Paralepididae	
Notolepis rissoi (Bonaparte) 1840	2(1,24), 4(5,27), 5(1,0), 7(1,2), 8(1,1), 10(6,7)
Saccopharyngidae	
Saccopharynx ampullaceus (Harwood 1827)	8(1,10)
Searsidae	
Pellisolus facilis Parr 1951	6(1,2), 8(1,32)
Serrivomeridae	
Serrivomer beani Gill and Ryder 1883	2(1,16), 4(2,59), 5(4,48), 6(17,860), 7(4,156), 8(13,342), 9(5,16), 10(6,36)
Sternoptychidae	
Argyropelecus aculeatus Cuvier and Valenciennes 1849	9(1,0)
Sternoptyx diaphana Hermann 1781	4(4,5), 5(1,2), 10(15,24)
Stomiatidae	
Stomias boa ferox Reinhardt 1842	2(104,1039), 3(27,200), 4(42,722), 5(12,207), 6(41,754), 7(19,262), 8(17,186), 9(6,10), 10(12,286)

Note: Weights were rounded to the nearest gram; a weight of 0 indicates a total weight less than 0.5 gm.